DESIGN AND ANALYSIS OF MICROSTRIP ANTENNAS FOR ULTRA- WIDE BAND APPLICATIONS

A thesis in partial fulfillment of the requirements for the degree of

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In

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By

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To discover, analyze and to present something new is to venture on an untraded path towards and unexplored destination is an arduous adventure unless one gets a true torchbearer to show the way. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various people. Words are often too less to reveals one's deep regards. I acknowledge with gratitude and humility my indebtedness to **PG Co-ordinator Prof. P.K. Sahu , Associate Professor,** Electrical Engineering Department, N.I.T Rourkela, under whose guidance I had the privilege to complete this report . I wish to express my deep gratitude towards her for providing individual guidance and support throughout this work.

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CERTIFICATE

This is to certify that the work in this thesis entitled "**DESIGN AND ANALYSIS OF MICROSTRIP ANTENNA FOR ULTRA-WIDE BAND APPLICATIONS"** by Mr. **Devasis Pradhan** is a record of an original research work carried out by him during 2014 - 2015 under my supervision and guidance in partial fulfillment of the requirement for the award of the degree of Master of Technology in Electronics System & Communication , National Institute of Technology, Rourkela.

Neither this thesis nor any part of it, to the best of my knowledge, has been submitted to any other University/ Institution elsewhere for award of any degree or diploma..

Date…29/05/2015………………………………

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Declaration

I certify that

a) The work comprised in the thesis is original and is done by myself under the supervision of my supervisor.

b) The work has not been submitted to any other institute for any degree or diploma.

c) I have followed the guidelines provided by the Institute in writing the thesis.

d) Whenever I have used materials (data, theoretical analysis, and text) from other sources, I have given due credit to them in the text of the thesis and giving their details in the references.

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Abstract

A Microstrip fed antenna which consists of a rectangular patch with rectangular shaped slot incorporated into patch is presented for ultra wide band application with enhanced bandwidth. The proposed antenna achieves an impedance bandwidth of 3.8-11.1GHz with for over the entire UWB bandwidth. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. The proposed antenna is designed on low cost FR-4 substrate fed by a 50-Ω microstrip line. The simulation was performed in CST 2012 software . The antenna parameters such as resonant frequency, return loss, radiation pattern and VSWR are simulated and discussed in this paper. The several factors affecting the bandwidth of the microstrip antenna such as the thickness of the substrate, the dielectric constant of the substrate and the shape of the patch also studied in this paper. The parametric study also contains the study of different techniques for optimizing the different parameters of antenna to get the optimum results and performance. This is a simulation based study. The first design is the two slotted rectangular micro-strip patch antenna and using DGS(Narrow Band). The second design based on RMSPA with single slot with partial ground plane and third and fourth design is based on circular and elliptical patch in which various antenna parameters like return loss, VSWR, directivity, and gain are studied for antenna designing. Now a days it is essential for an antenna designed for a system to avoid the interference from the other existing wireless system. The antenna should possess a band reject characteristic at interfering frequency bands. This can be achieved with the help of Band Notched Characteristics.

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Glossary

Q	Quality Factor
Wp	Patch Width
Lp	Patch Length
εreff	Effective Dielectric Constant
ΔL	Frings factor
Leff	Effective Length
S-parameters	Scattering Parameters
Wg	Width of Ground
Lg	Length of Ground
h	High of Substrate
Wf	Width of Feed Line
Lf	Length of Feed Line
3D	Three Dimensions
D	Directivity
G	Gain
fr	Resonance Frequency
fc	Center Frequency
GHz	Giga Hertz
C	Speed of Light
λ_0	free Space wane length
λ_g	Guided Wavelength
Z_0	Characteristic Impedance
U_0	Radiation Average Intensity Overall Direction
U	Radiation Intensity in a given Direction
U_{max}	Maximum Radiation Intensity
P_{rad}	Total Power Radiation by Antenna
η_{rad}	Radiation Efficiency

ABBREVIATIONS

BW	Bandwidth
CMSP	Circular Microstrip Patch
CP	Circular Polarization
CST	Microwave Studio
dB	Decibel
dBi	Decibel-isotropic
DGS	Defect Ground Structure
EM	Electromagnetic waves
FDTD	Finite Difference Time Domain
FEM	Finite Element Method
GHz	Giga Hertz
GSM	Global System for Mobil
IEEE	Institute of Electrical and Electronics Engineers
MOM	Methods of Moments
MHz	Mega Hertz
MSPA	Microstrip Patch Antenna
MSP	Microstrip Patch
PDF	Partial Differential Equation
Radar	Radio Detection and Ranging
RF	Radio Frequency
RL	Return Loss
RMPA	Rectangular Microstrip Patch Antenna
TEM	Transverse Electromagnetic waves
UWB	Ultra Wide Band
VSWR	Voltage Standing Wave Ratio
WiFi	Wireless Fidelity
WIMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

CHAPTER 1

1.1 Introduction

In our day to day life mobile communication system has become a part of our civilization . Most of the electrical and electronics equipments are working on wireless system. An antenna is an essential unit of wireless system. It is device which radiate the electromagnetic waves into the space by converting the electric power given at the input into the radio waves and at the receiver side the antenna intercepts these radio waves and converts them back into the electrical power. Antenna are basically used in remote controlled television, cellular phones, satellite communications, spacecraft, radars, wireless phones and wireless computer networks. In the modern wireless world, the need for smaller, broadband and reliable antennas has been fully demonstrated in current advancements in communication industry and significant growth in wireless communication market and consumer demand.

A microstrip antenna is one who which offers low profile and light weight. It is a wide beam narrowband antenna can be manufactured easily by the printed circuit technology such as a metallic layers in a particular shape is bonded on a dielectric substrate which forms a radiating element and another continuous metallic layer on the other side of substrate as ground plan, not only the basic shapes any continuous shape can be used as the radiating patch. Moreover, they are easily integrated into arrays or into microwave printed circuits. [1-2]

The size of microstrip antenna is related to the wavelength of operation generally $\lambda/2$. The applications of microstrip antennas are above the microwave frequency because below these frequency the use of microstrip antenna doesn’t make a sense because of the size of antenna. At frequencies lower than microwave, microstrip patches don't make sense because of the sizes required. Now a day’s microstrip antenna is used in commercial sectors due to its inexpensiveness and easy to manufacture benefit by advanced printed circuit technology[3]

1.2 Objective of Work

Basic shapes of the microstrip patch are rectangular, square, circular, triangular, etc. All these have been theoretically studied and there are well established design formulae for each of them. So, here a new designed of microstrip antenna which will cover the entire Ultra Wide Band.

One of the major problem for UWB systems are electromagnetic interference (EMI) from existing frequency bands, because there are many other wireless narrowband application that are allocated for different frequencies band in the UWB band. In order to avoid this interference different technique were used such as DGS , partial ground with notch etc. The goal of this thesis is to study how the performance of the antenna depends on various parameters of microstrip patch antenna. This is a simulation based study. CST Microwave studio software, one commercial 3-D full-wave electromagnetic simulation software tool is used for the design and simulation of the antenna. Then, the antenna parameters are varied to study the effect of variation of the antenna parameters on the antenna performance based on bandwidth enhancement and gain.

1.2 Thesis Organization

The Thesis is organized as follows:-

a) **Chapter One** presents introduction to microstrip patch antenna and also concluded with the details of outline of the present thesis.
b) **Chapter Two** is dedicated to UWB Technology and scheme use for data transmission.
c) **Chapter Three** is dedicated to Literature Survey of my thesis gives an overview about the microstrip antenna; working principle of microstrip antenna, advantages and disadvantages as compare to their counterpart and finally the major applications in different fields. Different feeding method were also discussed.
d) **Chapter Four** presents basic parameters on the selection and performance of an antenna is characterize, are Bandwidth, Antenna Polarization, radiation, Pattern, Efficiency, Antenna Gain are explained briefly.
e) **Chapter Five** In this chapter microstrip patch Rectangular and Circular patch is discussed and also deals with the design parameters are calculated and their effect on the antenna performance.
f) **Chapter Six** This chapter deals with the design and simulation of microstrip patch antenna of different shapes. Different method are used to increase the bandwidth and gain are also applied. The simulated results and graphs characterizing the antenna performance are plotted and the effect of various antenna parameters on the antenna performance is also observed and compared and shown in the chapter.
g) **Chapter Seven** includes the conclusion and future works.

CHAPTER 2

UWB Technology

UWB technology has been used in the areas of radar, sensing and military communications during the past 20 yea. FCC issued a ruling that UWB could be used for data communications as well as for radar and safety applications . Since then, UWB technology provide rapidly advancing as a promising high data rate wireless communication technology for various applications. This chapter presents a brief overview of UWB technology and explores its fundamentals, including its definition, advantages, current regulation state and standard activities.

2.1 Overview

UWB systems have been historically based on impulse radio because it transmitted data at very high data rates by sending pulses of energy rather than using a narrowband frequency carrier. The concept of impulse radio initially originated with Marconi, in the 1900s, when spark gap transmitters induced pulsed signals having very wide bandwidths . As a result, wideband signals caused too much interference with one another.

In 1942-1945, several patents were led on impulse radio systems to reduce interference and enhance reliability. It is in the 1960s that impulse radio technologies started being developed for radar and military applications.

In the mid 1980s, the FCC allocated the Industrial Scientific and Medicine (ISM) bands for unlicensed wideband communication use. Owing to this revolutionary spectrum allocation, WLAN and Wireless Fidelity (Wi-Fi) have gone through a tremendous growth in present scenario.

In February, 2002, the FCC amended the Part 15 rules which govern unlicensed radio devices to include the operation of UWB devices. The FCC also allocated a bandwidth of 7.5GHz, i.e. from 3.1GHz to 10.6GHz to UWB applications, by far the largest spectrum allocation for licensed use the FCC has ever granted. According to the FCC , any signal that occupies at least 500MHz spectrum can be used in UWB system.

2.2 Modulation Scheme

In UWB system following modulation scheme were used to transmit data such as PAM, PPM, BPSK and so on.[]

a) **Pulse Amplitude Modulation** :- In PAM scheme information is encoded based on the amplitude of the pulses shown in fig.

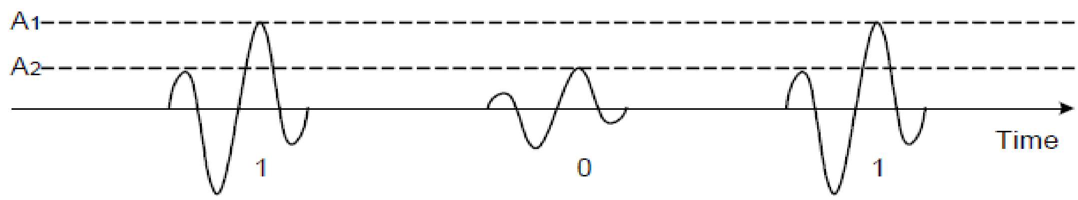


Fig. 2.1 PAM Scheme

The transmitted pulse amplitude modulated information signal y(*t*) can be represented as:

$$y(t) = d_i * w_{tr}(t) \ldots\ldots (2.1)$$

where w_{tr} (*t*) denotes the UWB pulse waveform, *i* is the bit transmitted (i.e. `1' or `0'), and

$$d_i = A_1 = 1; A_2 = 0 \ldots\ldots (2.2)$$

b) PPM

In PPM, the bit to be transmitted determines the position of the UWB pulse. As shown in Figure, 2.2 the bit `0' is represented by a pulse which is transmitted at nominal position, while the bit `1' is delayed by a time of *a* from nominal position. The time delay *a* is normally much shorter than the time distance between nominal positions so as to avoid interference between pulses.

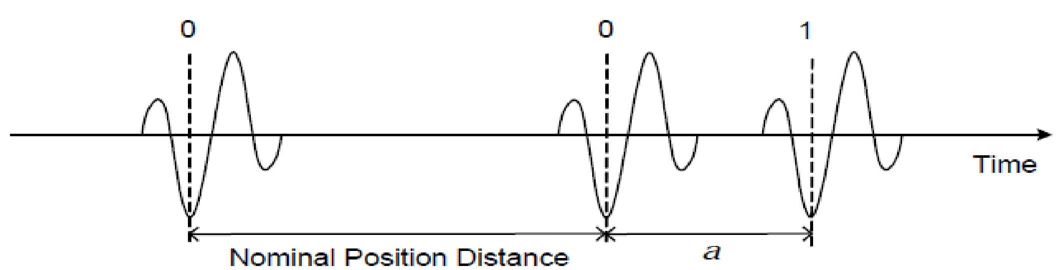


Fig. 2.2 PPM Scheme

Let Pulse Modulated signal is y(t)

$$y(t) = w_{tr}(t - a*d_i) \ldots\ldots (2.3)$$

$$\textit{where } d_i = 1 \textit{ at } i=1$$

$$d_i = 0 \text{ at } i = 0 \ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

c) BPSK

In BPSK modulation, the bit to be transmitted on the basis of the phase of the UWB pulse As shown in Figure2.3 , a pulse represents the bit `0'; when it is out of phase, it represents the bit `1'bit is in phase .

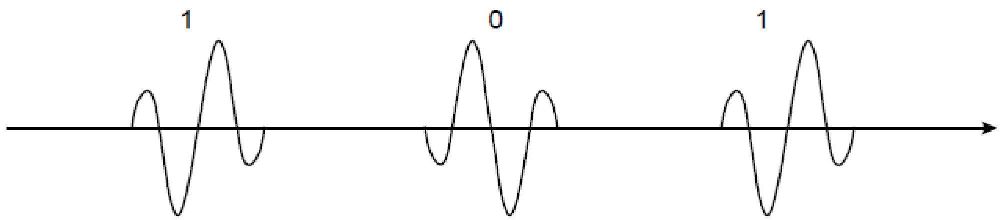


Figure 2.3: BPSK modulation

Let BPSK modulated signal y(t) can be represented as:

$$y(t) = wtr(t) * e^{-j(d*\pi)} \ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

$$\text{where } d_i = 1 \text{ at } i=1$$

$$d_i = 0 \text{ at } i = 0 \ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

2.3 Frequency Band Assignment

The UWB band covers a frequency spectrum of 7.5GHz. The wide band can be utilized with two different approaches: single-band scheme and multiband scheme.

1. Single- Side Band Scheme:- It is based on impulse radio and transmit short pulses in order to cover entire UWB band. Basically data were transmitted on a scheme of PPM and it support time hopping method or scheme. In this scheme each frame, consist of eight time slots allocated to eight users; for each user, the UWB signal is transmitted at one specific slot which determined by a pseudo random sequence.

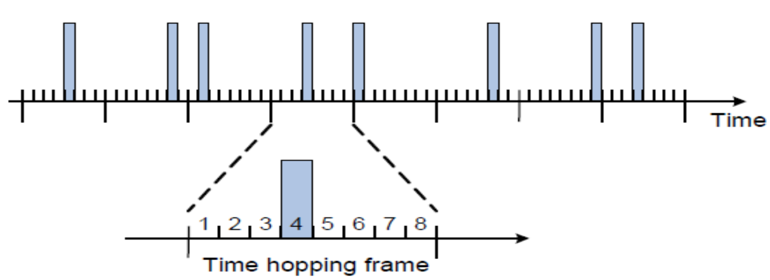


Fig. 2.4 Time hopping Scheme

2. Multi- Band Scheme:- In this scheme 7.5 GHz UWB band is divided into several smaller sub band and each sub band with bandwidth not less than 500 MHz confirm by FCC. In this scheme frequency hopping method is use due to which multiple access is performed. At any time, only one sub-band is active for transmission while the so-called time-frequency hopping codes are exploited to determine the sequence in which the sub-bands are used.

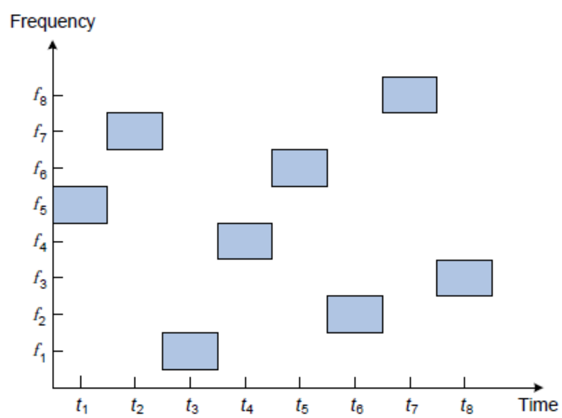


Fig 2.5: Frequency hopping concept

2.4 Advantage of UWB

1. As we, know Channel capacity is directly proportional to bandwidth. UWB has an ultra wide frequency bandwidth due to which e huge capacity is achieved as high as hundreds of Mbps or even several Gbps with distances of 1 to 10 meters.
2. Basically UWB system operate in extremely low power transmission level.
3. It provide high security and reliable communication network.
4. UWB system generally use impulse radio features at low cost and low complexity which arise from the essentially baseband nature of the signal transmission.
5. Main advantage is there is no modulator or demodulator or mixer is require because in this there is no utilization of complex carrier wave.

CHAPTER 3

Antenna Theory

The main objective of my thesis is to design antennas that are suitable for the UWB communication systems. Before to proceed with my design work, it is necessary to get familiar with the fundamental antenna theory in this chapter. The parameters that always have to be considered in antenna design are described in this chapter . Some general approaches to achieve wide operating bandwidth of antenna are presented.

The important parameter are discussed as follows:-

3.1 Frequency Bandwidth

A bandwidth is considered to be the range of frequencies, on either side of the center frequency, where the antenna characteristics are within an acceptable value of those at the center frequency. Basically in mobile communication , the antenna is required to provide a return loss less than -10dB over entire bandwidth.

The bandwidth of antenna basically expressed in two form such as ABW or FBW.

$$ABW(Absolute\ Band\ Width) = f_h - f_l \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.1)$$

$$FBW(Fractional\ Band\ width) = 2*[(f_h - f_l)/(f_h + f_l)] \quad \ldots\ldots\ldots\ldots\ldots\ldots(3.2)$$

f_h= higher frequency; f_l= lower frequency with respect to centre frequency.

3.2 Radiation Pattern

Antenna Pattern is also called as Far-Field Pattern. Radiation pattern is a graphical representation of radiated power at as fix distance from the antenna as a function of azimuthal and elevation angle. Basically it represent the power is distributed in the space of 2D plane for different azimuth and elevation angle referred as azimuth plane pattern and elevation plane pattern.

This pattern can be represented in Cartesian (rectangular) coordinates. . There are different types of antenna patterns described below:-

a) **Isotropic:-** In this pattern t has equal radiation in all direction. It is applicable for ideal one.

b) **Directional:-** It have a property to radiate or receive electromagnetic wave from some direction than the other. Basically this antenna have large directivity in a particular direction.

c) **Omni- directional:-** An antenna having an essentially non-directional pattern in a given plane and a directional pattern in any orthogonal plane.

3.3 Directivity and Gain

a) Directivity:- It is a ratio of maximum radiation intensity to average radiation intensity from an antenna from an isotropic source.[]

$$D = U/U_0 = 4\pi U/P_{rad} \ldots\ldots\ldots\ldots(3.3)$$

Where $U_0 = P_{rad}/4\pi$

b) Gain:- Antenna gain *G* is closely related to the directivity, it is basically product of radiation efficiency with directivity.

$$G = \eta_{rad} \times D \ldots\ldots\ldots\ldots\ldots\ldots(3.4)$$

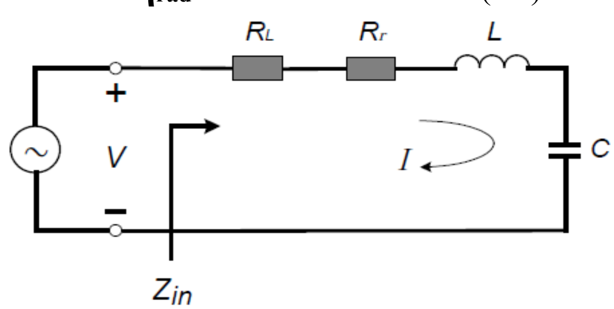


Fig. 3.1 Equivalent circuit model of antenna

Radiation efficiency = $\eta_{rad} = [\frac{1}{2}(I^2R_r)]/[1/2(I^2(R_r+R_L))] = R_r/[R_r+R_L] \ldots\ldots\ldots(3.4)$

3.4 Antenna Polarization

Basically it is a orientation or path of electric field vector as a function of time. These orientation are broadly divided into three category:- elliptical, circular & linear polarization. If field vector follows the linear path then it is call linear polarization. These are of vertical and horizontal type. Whereas if field vector follows circular path or elliptical path then it is circular or elliptical polarization. These are identified with their rotation. If rotation is clockwise then it is called left hand polarized whereas if anticlockwise rotation takes place then it is called right hand polarized.

3.5 Far Field Region

The field regions are categorized in two forms such as Far field region and Near Field (Fresnel) Region. **Far field region** :- it is a region beyond the Fraunhofer distance called Fraunhofer region. After this region radiation pattern does not change with the distance. The Fraunhofer distance is related to antenna's larger dimension.

$$R = 2D^2/\lambda \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

R- distance from radiating element

D- dimension of radiating element

λ- wave length in free space

CHAPTER 4

Literature Review On Microstrip Antenna

4.1 Introduction to MSPA

Early in the 1970's, the first designs and theoretical models appeared . Due to its simplicity and compatibility with printed-circuit technology, widely used in microwave applications such as cellular phones and satellite communications. These are of low profile, mechanically robust, inexpensive to manufacture, compatible with MMIC designs and relatively light and compact. These are quite versatile in terms of resonant frequencies, polarization, pattern and impedance. It also have some drawbacks including low efficiency (due to dielectric and conductor losses), low power, spurious feed radiation (surface waves, strips, etc.), narrow frequency bandwidth. But with recent technology advancement and extensive research into this area these problems are being gradually overcome. The MSA(microstrip antenna) is called as patch antenna.
Basically patch antenna is made up of copper or gold and it can be form in any shape. The radiating element and feed line were usually photo etched .The radiating patch can be in form of square, rectangle, thin strip, circular or elliptical etc, out of which rectangular form is commonly used.

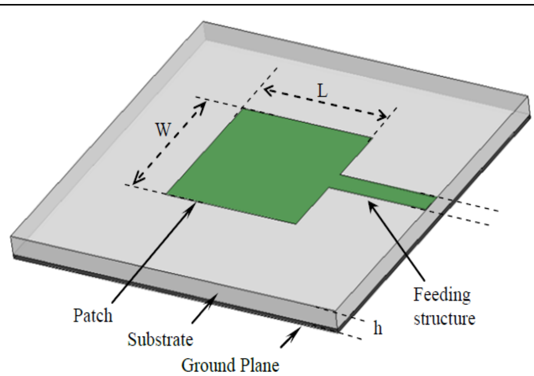


Fig. 4.1(a) Microstrip Antenna

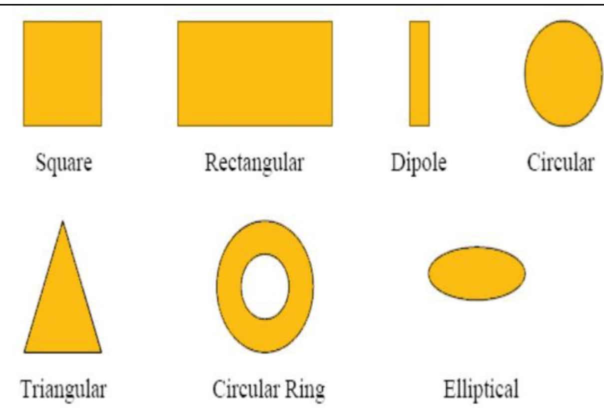


Fig. 4.1(b) Basic Common Shape

Fig. 4.1 Basic Structure of Patch antenna

a) Patch Length(L) is usually must be in a range of $\mathbf{0.33\lambda_0<L<0.5\lambda_0}$, where λ_0 is wavelength in free space,

b) Thickness of patch (Mt) and it must be **$Mt \ll \lambda_0$**

c) Thickness of Substrate (h) and it must be in range of **$0.003\lambda_0 < h < 0.05\lambda_0$**

d) Dielectric constant ε_r ($2.2 < \varepsilon_r < 12$)

4.2 Advantage and Disadvantage

a) Advantage:-

1. It has light weight, low volume, thin film which easily conforms to the surface of the product or vehicle.
2. It was cheap in rate, easy amenability to mass production, & easy integration with MIC's.
3. Generally it can produce linear and circular polarization with broadside radiation patterns.
4. Due to its compactness it is used in mobile phone.
5. These can produce multiple band allow for dual and triple frequency operations.

b) Disadvantage:-

1. It has Low efficiency & Low power.
2. Poor polarization purity, poor scan performance.
3. It Provide narrow band width.
4. It has low gain about (~6dB.).
5. Quality factor is very high due to its narrow band width.
6. Conductor and Dielectric Losses were high.

4.3 Application:-

1. Satellite communication;
2. Doppler and other radars;
3. Radio altimeter;
4. Command and control systems;
5. Missiles and telemetry (stick-on sensor and weapon fusing);
6. Remote sensing and environmental instrumentation;
7. Feed elements in complex antennas;
8. Satellite navigation receivers;
9. Biomedical radiator;

10. Mobile radio;
11. Integrated antennas;
12. Global Position Systems (GPS).

4.4 Feeding Technique

There are variety of methods used to fed MSA. It was broadly divided into two categories-contacting and non-contacting.

In the ***contacting method***: - the RF power is fed directly to the radiating patch using a connecting element such as a microstrip feed line. Where as in the ***non-contacting scheme:-*** electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch.

Broadly the feed techniques are as follows:-

a) microstrip line,
b) coaxial probe (both contacting schemes),
c) aperture coupling and
d) proximity coupling (both non-contacting schemes).

4.4.1 Microstrip Feed Line

In this technique the conducting strip is directly connected with edge of microstrip patch. The dimension of strip is quite smaller than patch dimension with respect to width, shown in Fig 4.2 below.

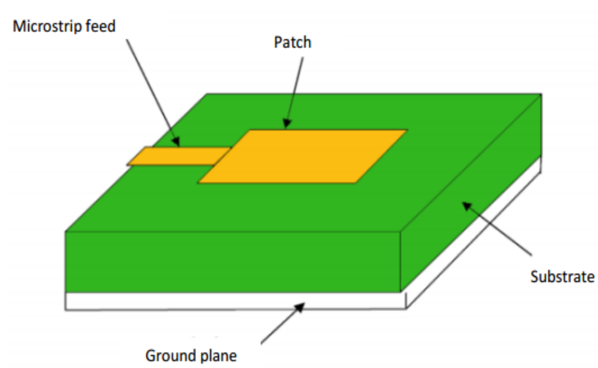


Fig. 4.2 Microstrip Antenna with Feed Line

4.4.2 Co- axial Probe

In this method a co-axial connector is connected to ground plane and coaxial center conductor extends through the substrate and is attached to the radiating patch. This is illustrated in a Fig 4.3 shown below. The position of the feed in co-axial probe must be one third distance from centre.

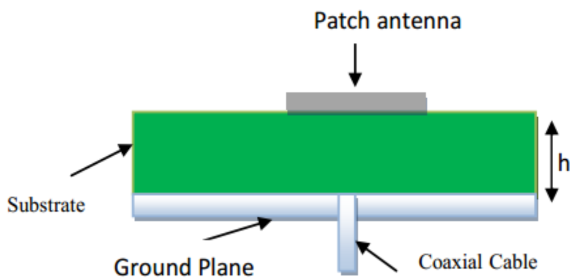


Fig. 4.3 Co-axial Probe Feed Technique.

4.4.3 Aperture Coupled Feed:-

In this technique the patch and feed line are place on different side of ground plane .A slot is cut on ground plane so that electromagnetic couple takes place between patch and feed line and no connector is used between them. This feeding technique is used to avoid spurious radiation as shown in Fig. 4.4 below.

4.4.4 Proximity Coupling:-

In this technique two dielectric substrate are used such that in upper layer patch is present where as feed line is placed on the lower layer of substrate. This technique is shown in Fig. 4.5. The main advantage of this method is used eliminate spurious radiation and provide high band width due to increase in thickness of substrate layer.

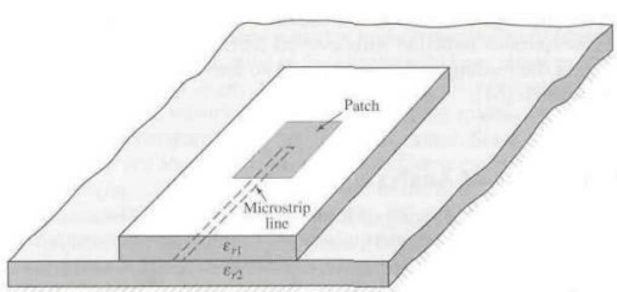


Fig. 4.5 Proximity Coupling Technique.

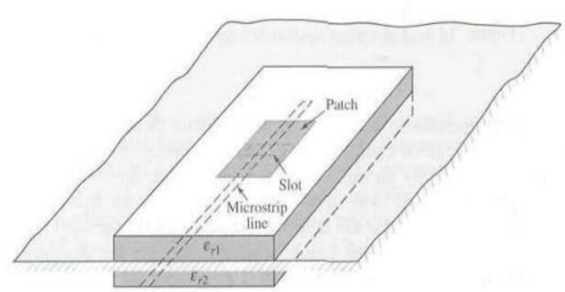


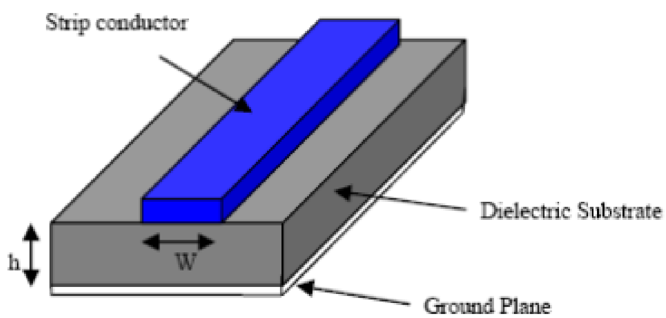
Fig. 4.4 Aperture Couple Feed Technique

CHAPTER 5

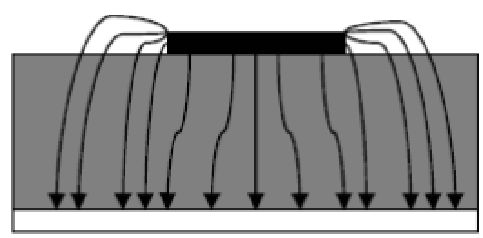
FUNDAMENTAL CONCEPT ON RECTANGULAR & CIRCULAR PATCH

5.1 Rectangular MSPA

The RMSPA is commonly used to designing purpose. The figure 5.1 shows below is a rectangular patch antenna. In this designer can vary length and width of patch in order to achieve the required band width . This metallic patch is separated from the ground plane by a fraction of wavelength distance above by the dielectric substrate. The fringing fields are coming out from the edges are shown in Fig. 5.1



(a) Microstrip line



(b) Electric fiel lines

Fig. 5.1 Mictrostrip Patch Antenna and Fields

5.2 Methodology

Basically there are two methods commonly used to model patch antenna is transmission line mode l and cavity model.[4,5]

5.2.1 Transmission Line Model

Transmission line model basically consist of two slot of width(W) and height (h) separated by low impedance Z_0 of certain length (L). The edge of the patch undergoes fringing effect as shown in Fig 5.1 . If w/h >>1 and ε_r>>1 then the field were concentrated in substrate. This ratio plays a vital role to identify the effective dielectric constant $\varepsilon_{reff} < \varepsilon_r$.

The expression for ε_{reff} is shown below.

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right) \left[1 + 12\,\frac{h}{W}\right]^{-\frac{1}{2}} \qquad \text{…………………(5.1)}$$

W- width of patch, h- height of substrate.

Wavelength in dielectric medium is given by $\boldsymbol{\lambda = \lambda_0 / \sqrt{\varepsilon_{reff}}}$

Due to fringing effect patch look greater than its original dimension as shown in Fig. 5.2.

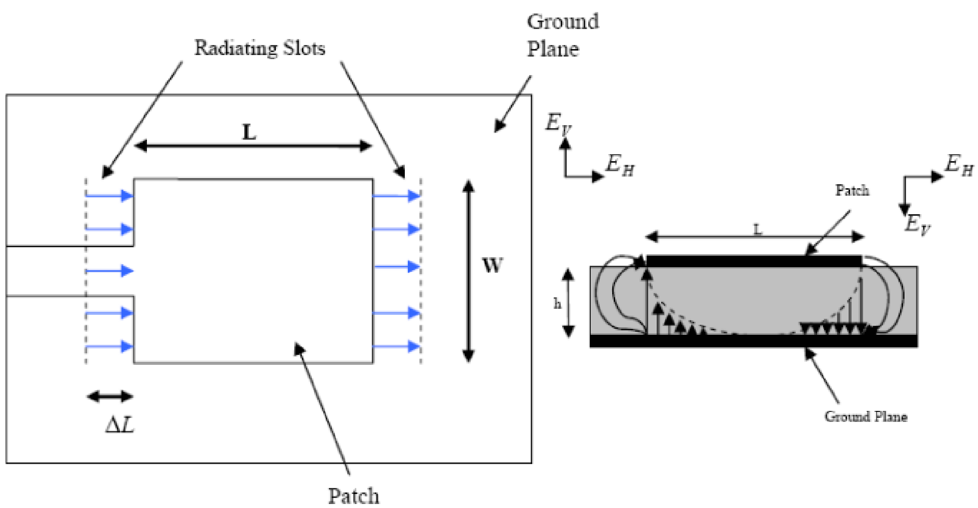


Fig. 5.2 Rectangular Patch Transmission Line Model

The parameter ΔL indicate the dimension enlargement of L due to fringing effect and depend upon w/h ratio.

$$\Delta L = 0.412h \left[\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right] \qquad \text{……………….(5.2)}$$

The effective Length of patch can be calculated as $L_{eff} = L + 2\Delta L$……………….(5.3)

For a given resonance frequency f_r , the effective Length can be calculated as L_{eff}

$$\boldsymbol{L_{eff} = L + 2\Delta L = \frac{\lambda_o}{2\sqrt{\epsilon_{reff}}} = \frac{c}{2f_r\sqrt{\epsilon_{reff}}}} \qquad \text{…………………………..(5.4)}$$

Using Fig. 5.3 the resonanting input impedance can calculated as follows:-

The equivalent admittance Y = G+jB……………………………………(5.5)

where G and B represents the conductance and the susceptance of slot or at radiating edge of patch antenna.

$$G = \frac{W}{120\lambda_0}\left[1 - \frac{1}{24}(k_0 h)^2\right] \qquad \frac{h}{\lambda_0} < \frac{1}{10}$$

$$B = \frac{W}{120\lambda_0}\left[1 - 0.6336 ln(k_0 h)\right] \qquad \frac{h}{\lambda_0} < \frac{1}{10}$$ ……………(5.6)

Thus resonant input impedance is calculated as follows R_i

$$R_{in}(y = 0) = \frac{1}{2(G_1 + G_{12})}$$ ………………………………(5.7)

G_{12}—mutual conductance between slot and edge of patch element can be calculated in term of Bessel function of order zero.(J_0)

$$G_{12} = \frac{1}{120\pi^2}\int_0^\pi \left[\frac{\sin\left(\frac{k_0 W}{2}\cos\theta\right)}{\cos\theta}\right]^2 J_0(k_0 L\sin\theta)\sin^3\theta\, d\theta$$ ………………………(5.8)

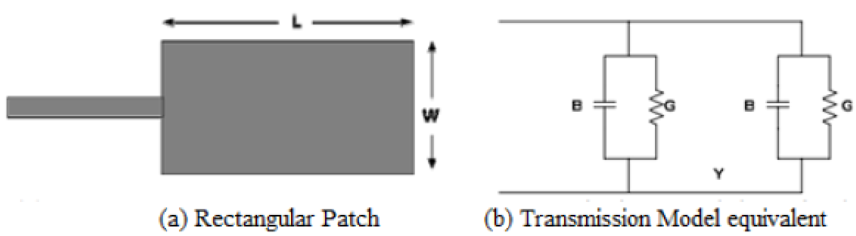


Fig. 5.3 Equivalent circuit model of Patch antenna

5.2.2 Cavity Model

Basically this model provide accurate result but it is more complex as compared to transmission line model. In this a magnetic wall is created between patch and ground plane as shown in Fig. 5.4.

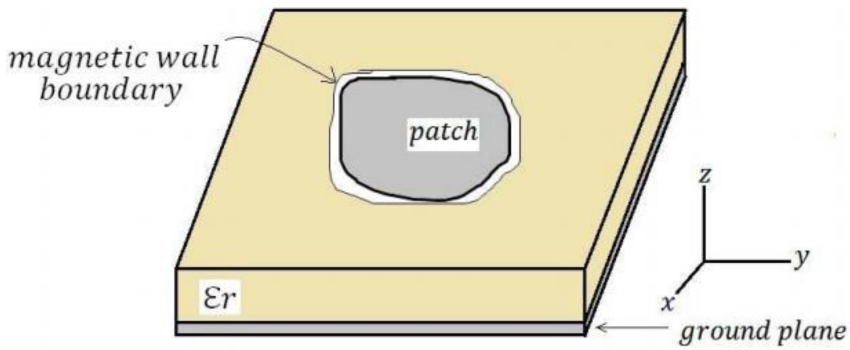


Fig. 5.4 Magnetic wall model of a microstrip patch antenna

The cavity model is formed with the help of certain assumption :-

1. Cavity consist of three fields such as E_z(Electric field along z-axis) and other two field component are H_x and H_y(Magnetic field along x and y- axis).
2. Since h<<λ field in the interior region do not vary with z-axis for all different frequencies.
3. There is no electric current component normal to edge of patch.

When source is provided to patch antenna charge distribution takes place as shown in Fig. 5.5 below.

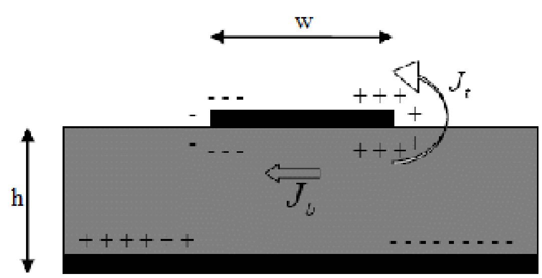


Fig. 5.5 Charge distribution on patch antenna

Relationship between the field component E_z , H_x and H_y as follows

$$\nabla \times \nabla \times \vec{E} - k^2\vec{E} = -j\omega\mu_0\vec{J}$$

$$\nabla^2 E_z - k^2 E_z = j\omega\mu_0\hat{Z} \bullet \vec{J} \qquad \text{……………………………(5.9)}$$

$$k^2 = \omega^2\mu_0\varepsilon_0\varepsilon_r \qquad \text{………………………………………..(5.10)}$$

$\overrightarrow{J}$ = Electric current density fed by the feed line to the patch.

$\hat{Z}$ Is the unit vector normal to the plane of the patch.

5.3 Circular Patch Antenna

As compared to RMSPA in which there we have two degree of freedom to control the characteristics of antenna , here we have only radius which is used to control the characteristics. The circular patch is shown in Fig. 5.6.

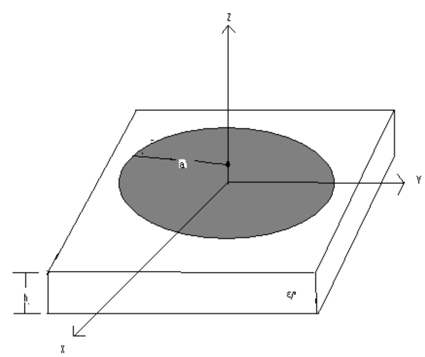


Fig.5.6 Circular Patch Antenna.

5.4 Methodology

Circular Patch antenna can be analyzed as cavity model with two conductor up and below of substrate and a magnetic wall is formed assumed at edges of patch.

Here the field component E_z(electric field along z- axis), and magnetic fields H_r and H_ϕ(along radius and azimuthal angle).[12]

$$E_z = E_0 J_n(kr)cos(n\emptyset) \quad \text{.....(5.11)}$$

$$H_r = -\frac{j\omega\varepsilon n}{k^2 r} E_0 J_n(kr)\sin(n\varphi)$$

$$H_\phi = -\frac{j\omega\varepsilon}{k} E_0 j_n'(kr)\cos(n\varphi) \quad \text{.....(5.12)}$$

where k- propagation constant, J_n- nth Bessel function, J_n' – nth derivative of Bessel function.

The effective radius and actual radius (a_{eff}, a)of circular patch antenna is as calculated as follows:-

$$a = \frac{X_{mn}.c}{2\pi\sqrt{\varepsilon_r}}.\left[1 + \frac{2h}{\pi a \varepsilon_r}\left(ln\left\{\frac{\pi a}{2f_{mn}h}\right\} + 1.7726\right)\right]^{-1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.13)$$

$$a_{eff} = a.\left[1 + \frac{2h}{\pi a \varepsilon_r}\left(ln\left\{\frac{\pi a}{2h}\right\} + 1.7726\right)\right]^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.14)$$

$$f_{mn} = \frac{X_{mn}.c}{2\pi\varepsilon_{eff}\sqrt{\varepsilon_r}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.15)$$

The terms X_{mn} = mth zero of derivative of Bessel's function of nth order

f_{mn}—Resonating frequency related to TM mode.

c- speed of light.

The conductance can be calculated based on radiated power.

$$P_{rad} = |V_0| \frac{(k_0 a_e)^2}{960} \int_0^{\pi/2} \left[J'_{02}{}^2 + \cos^2\theta J_{02}{}^2\right] \sin\theta d\theta \quad \ldots\ldots\ldots\ldots\ldots.(5.16)$$

Where , V_0

$$V_0 = hE_0 J_1(ka_e),\ \alpha = k_0 a_e \text{ and } k_0 = \frac{2\pi f_r}{v_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.17)$$

So, Conductance between ground plane and patch

$$G_{rad} = \frac{(k_0 a_e)^2}{480} \int_0^{\pi/2} \left[J'_{02}{}^2 + \cos^2\theta J_{02}{}^2\right] \sin\theta d\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.18)$$

Conductance due to conductor and dielectric losses

$$G_c = \frac{\varepsilon_{mo}\pi(\pi\mu_0(f_r)_{10})^{-3/2}}{4h^2\sqrt{\sigma}}\left[(ka_e)^2 - m^2\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.19)$$

$$G_d = \frac{\varepsilon_{mo}\tan\delta}{4\mu_0 h(f_r)_{10}}\left[(ka_e)^2 - m^2\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.20)$$

So, total conductance is $G_t = G_{rad} + G_c + G_d$

Resonance input impedance is also calculated as R_i

$$R_{in}(\rho' = \rho_0) = \frac{1}{G_t}\frac{J^2{}_m(k\rho_0)}{J^2{}_m(ka_e)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5.21)$$

CHAPTER 6

RESULTS & DISCUSSION

After going through the concept of a MSPA and its characteristics in the last chapter's , presently in this chapter we will deal with designing of the proposed microstrip patch antennas used in UWB band. Also, in this chapter, we also discuss about various methodology that are currently available to enhance the bandwidth and gain of patch antennas and which also affect the radiation characteristics of each design discussed briefly.

The basic configurations for standard microstrip antennas are used to design such as rectangular, elliptical and circular patches printed on an inexpensive FR-4 Epoxy substrate a dielectric constant (ε_r= 4.4) and high (h=1.5748mm), the design were presented on different geometrical form . The idea was to develop new configurations by modifying Defect Ground Structure , Partial Ground with notches and without notches and also some slits introduce in patch. The performance of the designed patch antenna is simulated with CST 2012 software.

6.1 Design 1. (Rectangular Patch Antenna with Slot and notch)

The three basic thing to be considered before design a RMSPA:- :

a) Resonant Frequency (f_0): The resonant frequency for this design is 7.5 GHz.

b) Dielectric constant of the substrate (ε_r): FR-4 Epoxy Substrate is used in this design(ε_r= 4.4). The dimension of Patch reduced with increase in dielectric constant.

c) Thickness of Substrate (h): For the microstrip patch antenna it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.5mm.

This antenna consist of a rectangular patch with rectangular stot is created on patch as well as partial ground structure is formed due to which narrow band patch antenna is modified to wide band antenna .Due to introduction of rectangular slit and partial ground the performance of patch antenna get increased and also due to variation of parameter including dimension.

6.1.1 Antenna design and parametric study.

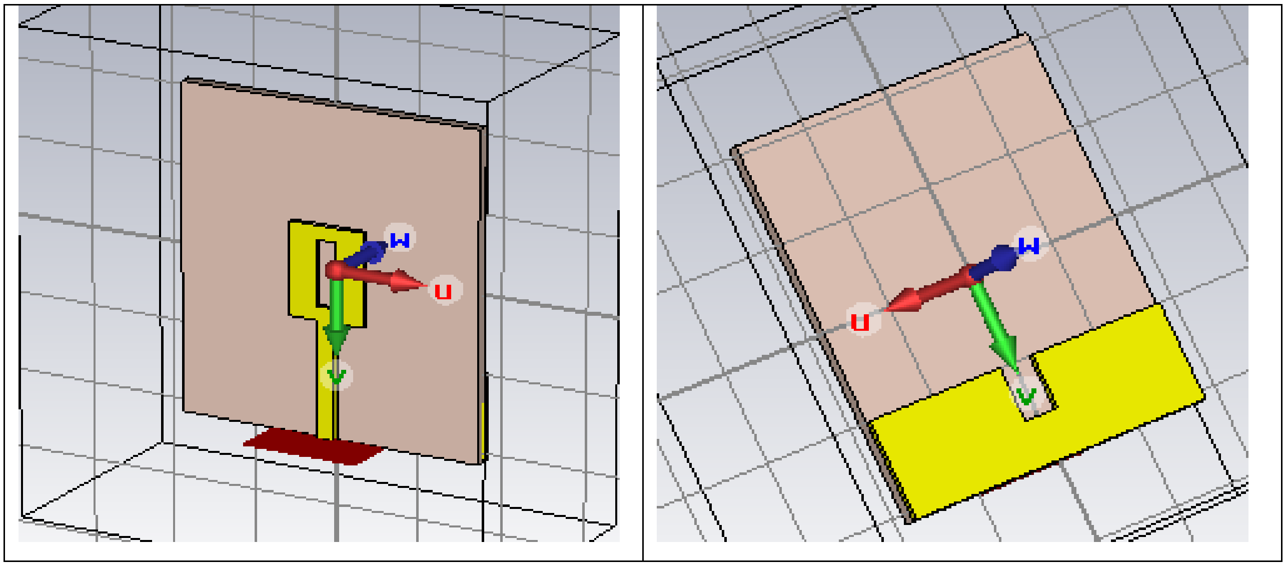


Fig. 6.1 Front and back view of Proposed MSPA

Table 6.1 Dimension of Antenna

Parameters	Description	Value
Lf	Length of feedline	8
Wf	Width of feedline	2
L1	Length of slot	5
W1	Width of slot	8
Lsub	Length of substrate	21
Wsub	Width of substrate	18
Wp	Width of patch	9
Lp	Length of patch	12

Operating Bandwidth Range = 4.53 GHz- 11.026GHz

Band width = 7.3 GHz, RL = -10.37dB, VSWR = 1.86 (<2)(acceptable).

The length Lg= 11.7mm has a very important role in controlling the coupling between ground plane and patch. This coupling causes to spread of the impedance bandwidth and hence must be accurately measured.

The proposed design is fed with standard 50ohm microstrip feed line. Different parameters with their Optimized value were shown in following tables.

6.1.2 Result and Discussion of Rectangular Slot Patch Antenna

The return loss, VSWR and gain for the designed antenna is shown in Fig 6.2 (a, b, c, d, e) respectively. The discussed design achieves the return loss of -10.37 dB and the bandwidth of 7.3 GHz (3.8- 11.1GHz) and corresponding VSWR is 1.86 < 2 for entire bandwidth range. These result will be used in UWB application.

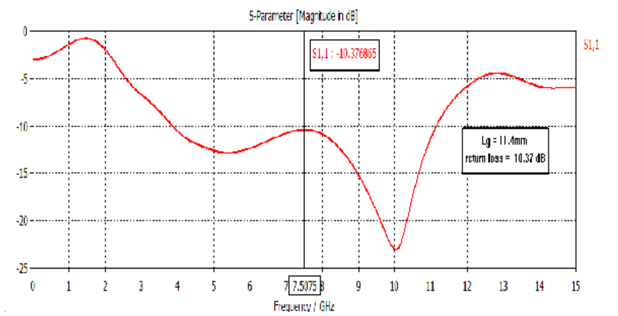


Fig.6.2(a) Return Loss = -10.37 dB

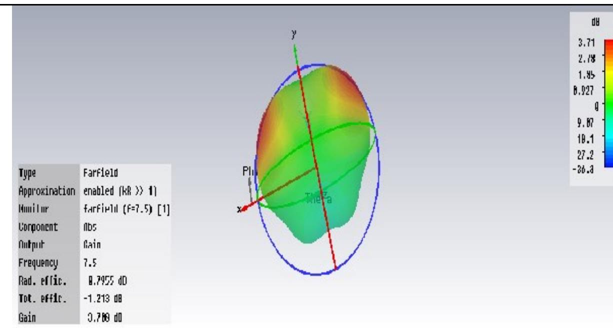


Fig.6. 2(b) Gain= 3.71 dB

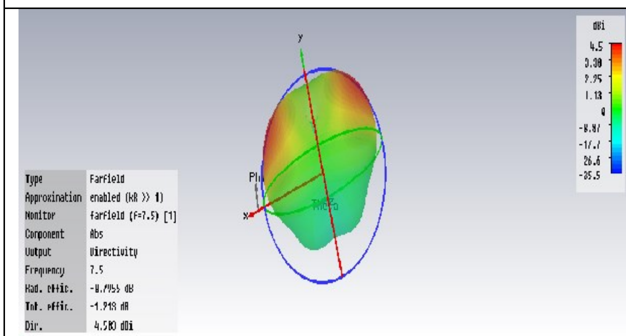


Fig.6.2(c) Directivity = 4.58 dB

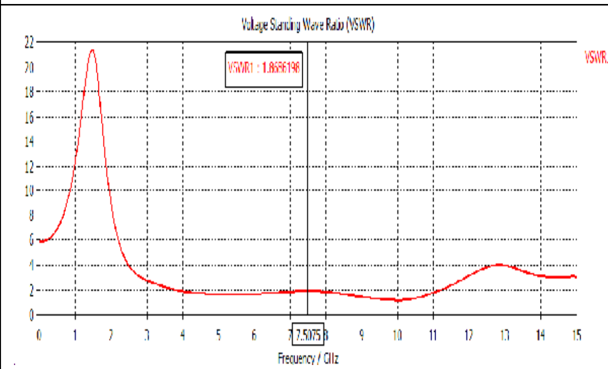


Fig6.2.(d) VSWR =1.6

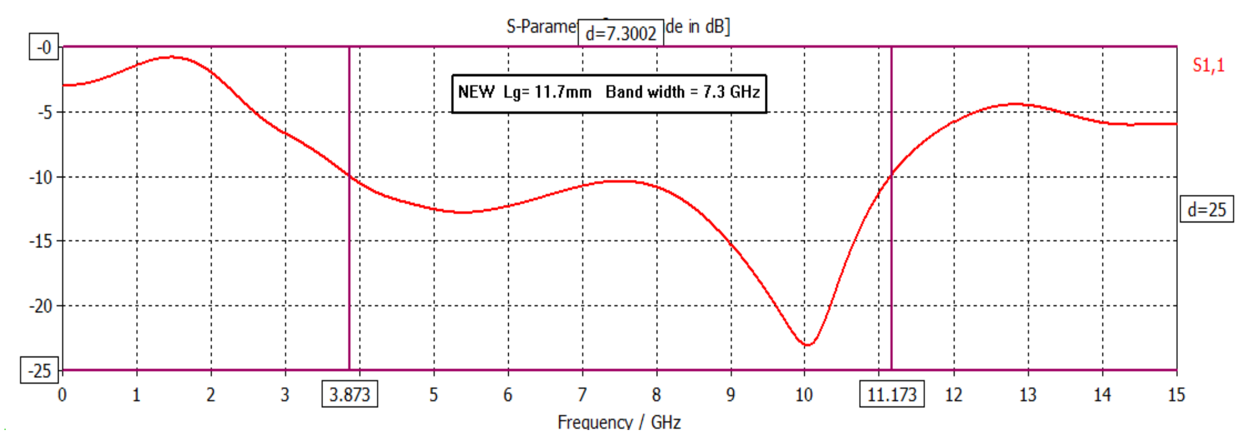


Fig.6. 2(e) Band Width =7.3 GHz

6.1.3Parametric Study of Rectangular Slot Wide Band Patch Antenna

(a) If substrate thickness was increased or decreased the bandwidth of the designed antenna with f_0 = 7.5 GHz were changing and also the RL And VSWR which is shown in Table 6.2.

Table 6.2 Variation of Thickness of substrate

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss	VSWR
1.	1.2	4.4	5.0-7.2 GHz 8.6-11.17 GHz	2.2 GHz 2.5 GHz	-8 dB	2.10
2	**1.5**	**4.4**	**3.8-11.1 GHz**	**7.3 GHz**	**-10.37 dB**	**1.86**
3	1.6	4.4	3.8-11.17 GHz	7.37 Ghz	-10.96 dB	1.78
4	1.7	4.4	3.7-11.179 GHz	7.47 GHz	-11.60 dB	1.71
5	1.9	4.4	3.7-5.98 GHz 6.4-11.13 Ghz	2.86 Ghz 4.72 Ghz	-13.06 dB	1.57

It is known that the easiest way to increase the bandwidth of a microstrip antenna is to print the antenna on a thicker substrate. Simulated Result while varying thickness h. **Fig6.3.(a, b, c, d)**

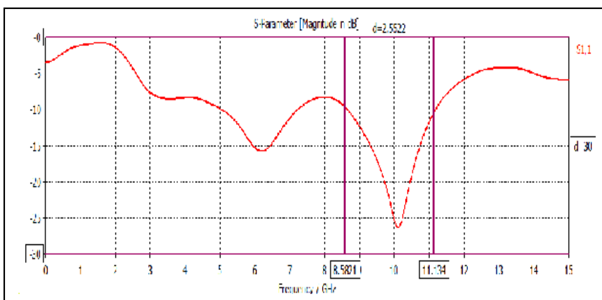


Fig. 6.3(a) h=1.2mm BW =2.2GHz, 2.5 GHz

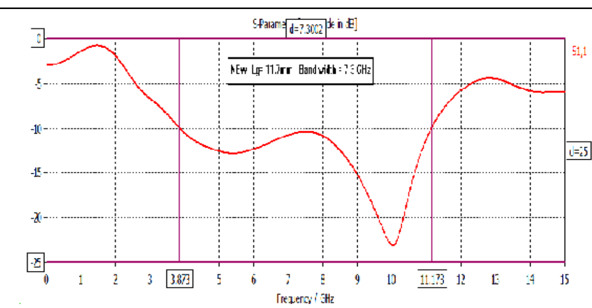


Fig6.3(b) h= 1.5mm BW =7.3 GHz

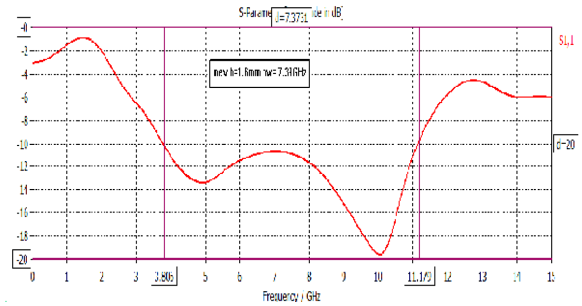


Fig.6. 3(c) h = 1.6mm BW = 7.37 GHz

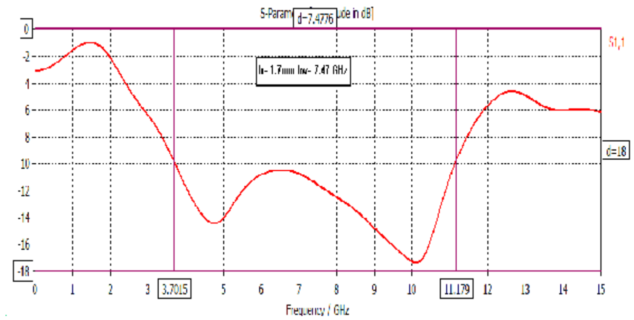


Fig6.3(d) h= 1.7 mm BW = 7.47GHz

b) If Slot Width and Length(W1, L1) are changed the Return Loss, VSWR and Band width also get changed with fixed dielectric constant = 4.4 shown in Table 6.3.

Table 6.3 Slot width and length is changed

No. Of Iteration	Slot Width and Length (mm)		Dielectric constant	Return loss dB	VSWR	Band Width GHz
1	W1= 3	L1= 5	4.4	-13.22	1.55	7.14 GHz
2	W1= 6	L1= 5	4.4	-12.13	1.65	7.23 GHz
3	W1= 6	L1= 6	4.4	-12.33	1.63	7.17 GHz
4	W1= 7	L1= 6	4.4	-11.63	1.70	7.23 GHz
5	W1= 8	L1= 5	4.4	-10.37	1.86	7.25 GHz
6	W1= 8	L1= 6	4.4	-10.64	1.83	7.15 GHz
7	W1= 9	L1= 5	4.4	-9.07	2.08	2.68 GHz, 3.07 GHz
8	W1= 9	L1= 6	4.4	-9.35	2.03	2.62 GHz, 3.07 GHz

c) Simulated Result of VSWR for h= 1.2mm, 1.5mm, 1.6mm, 1.7mm Fig6.4(a, b ,c, d)

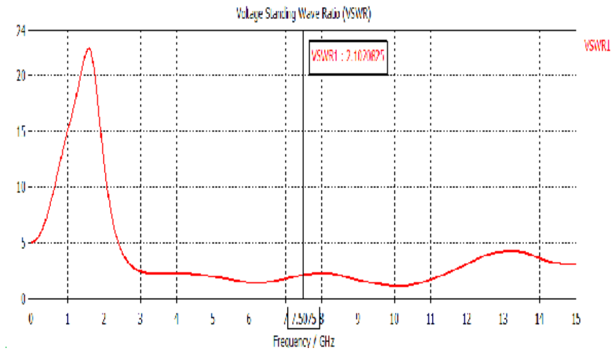


Fig. 6.4(a) VSWR =2.10, h= 1.2mm

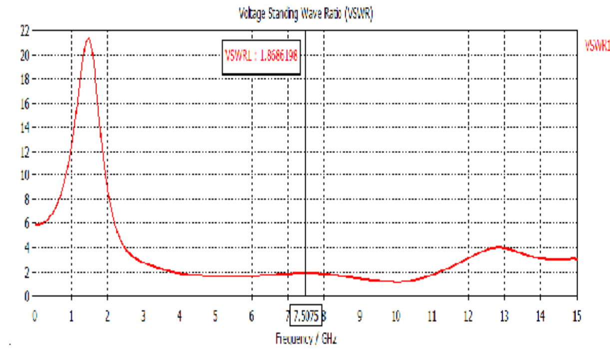


Fig.6. 4(b) VSWR =1.86, h= 1.5mm

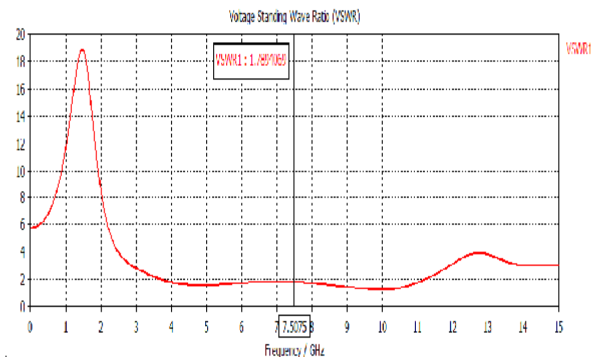


Fig. 6.4(c) VSWR = 1.78, h= 1.6mm

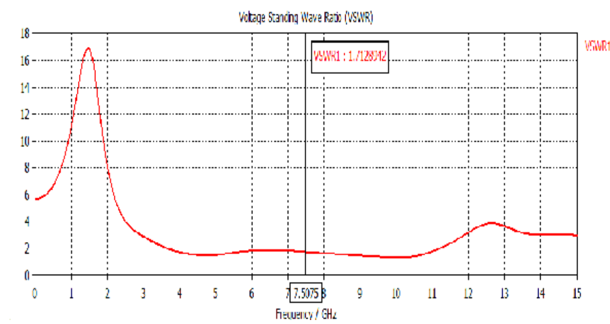


Fig.6. 4(d) VSWR = 1.71, h= 1.7mm

As the thickness is increasing the VSWR get reduced and also help in enhancing BW and gain.

d) If L_g is changed on ground plane it also affect the parameter of antenna which was shown in Table 6.4

Table 6.4 Variation in l_g

No. of Iteration	Lg (mm)	Return Loss(dB)	VSWR	Directivity (dB)	Gain(dB)	Band Width(GHz)
1	8	-12.41	1.62	5.487	5.23	1.28
2	9	-20.37	1.21	5.542	4.91	2.86
3	10	-24.01	1.31	5.130	4.5	4.52
4	11	-13.50	1.52	4.732	3.99	6.5

5	11.2	-12.52	1.61	4.66	3.98	6.92
6	11.3	-12.03	1.667	4.63	3.86	6.98
7	11.5	-11.15	1.76	4.57	3.78	7.07
8	**11.7**	**-10.37**	**1.86**	**4.58**	**3.71**	**7.30**
9	11.8	-10.02	1.92	4.47	3.67	7.26
10	11.9	-9.68	1.97	4.43	3.62	3.15, 8.2
11	12	-9.36	2.03	4.42	3.60	3.14, 2.9
12	13	-6.84	2.66	4.32	3.57	2.38, 2.1

e) Gain, Directivity, Return loss, Band Width and VSWR get changed due to change in notch width W_N at constant D_N from centre =16mm as shown in Table 6.5

Table 6.5 Variation in W_N (width of notch)

No. of Iteration	**Notch width W_N (mm)**	**Gain(dB)**	**Directivity (dB)**	**VSWR**	**Return Loss (dB)**	**Band Width (GHz)**
1	2	3.81	4.63	1.59	-12.76	1.5, 3.77
2	3	3.44	4.57	1.69	-11.8	1.7, 4.23
3	**4**	**3.71**	**4.58**	**1.86**	**-10.37**	**7.3**
4	5	3.62	4.41	2.09	-9.0	2.76,2.69

f) Gain, Directivity, Return loss, Band Width and VSWR also changed due to change in notch depth from centre D_N at constant W_N = 4mm ad shown in Table 6.6

Table 6.6 Variation in D_N

No. of Iteration	**Depth D_N (mm)**	**Gain(dB)**	**Directivity (dB)**	**VSWR**	**Return Loss (dB)**	**Band Width (GHz)**

1	14	3.81	4.59	1.42	-15.15	1.04, 2.8, 2.6
2	15	3.76	4.54	1.6	-12.16	7.6
3	**16**	**3.71**	**4.58**	**1.86**	**-10.37**	**7.3**
4	17	3.66	4.47	2.03	-9.33	2.3, 2.89

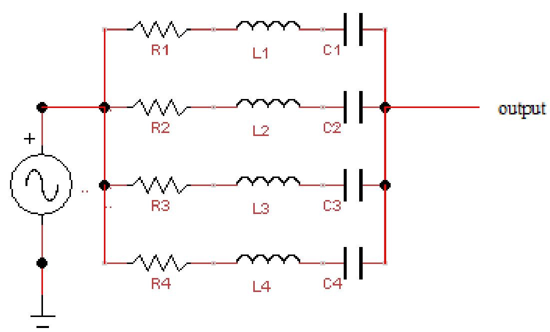
6.1.4 RLC circuit values for rectangular slotted MPA

The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Fig. 6.5

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ ………………………………..(6.1)

$f_r = \sqrt{(1/LC - (R/L)^2)}$…………………………(6.2)

Fig. 6.5 Equivalent RLC Model



The Parameter were calculated with the help of Z_0 =50 ohm= $\sqrt{(L/C)}$, and the parameter were shown in table 6.7.

Table 6.7 RLC value for designed antenna

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	3.9	R1= 7.9	L1= 2.04	C1= 0.81
2	5.5	R2= 6.43	L2= 1.44	C2= 0.57
3	10.2	R3= 4.27	L3= 0.78	C3= 0.31
4	11.2	R4= 9.89	L4= 0.7	C4= 0.28

6.2. Design 2 on Simple Circular Patch

The second design is circular patch antenna with partial ground plane structure . FR-4 Epoxy dielectric substrate is used with εr= 4.4. Characteristic impedance of 50 ohm microstrip feedline is used to fed to patch. . The results show that the proposed antenna has the bandwidth (vswr=1.42) bandwidth of 8.4 GHz comes under the UWB band therefore the this is a good antenna to be used for the UWB application. Partial ground plane is used here. In order to increase the bandwidth as a ground plane .

6.2.1 Dimension of Proposed antenna:-

Resonating Frequency	8.2 GHz
Length of Feed line(L_f)	7mm
Width of Feed(W_f)	2mm
Length of Substrate(L_s)	18mm
Width of Substrate(W_s)	12mm
Radius of Circular Patch(a)	5mm
Thickness of Substrate(h)	1.8mm
Thickness of Patch(Mt)	0.07mm

Table 6.7 Parameter and dimension of Antenna

6.2.2 Model of simple circular patch

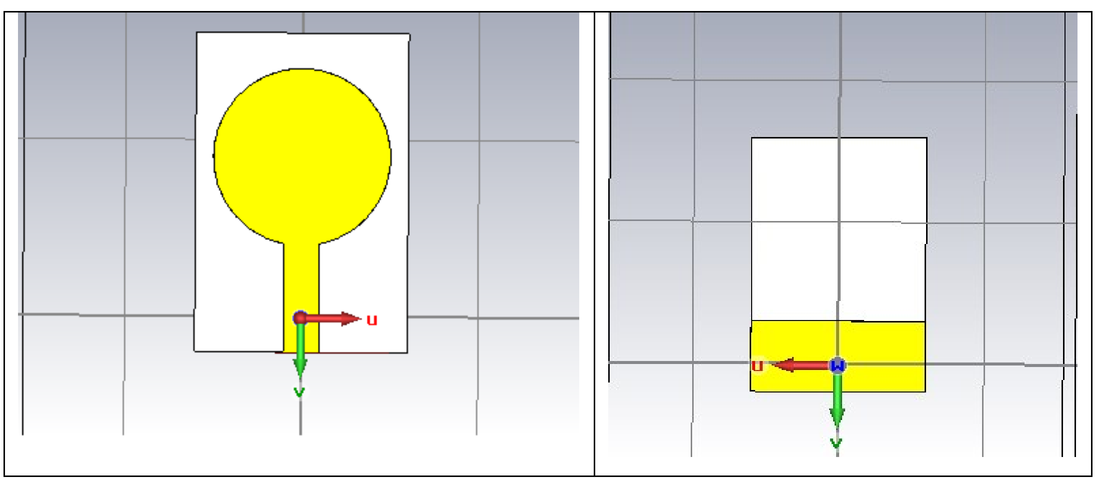


Fig 6.6 Model of Circular with feed line front and back view

6.2.3 Results and discussion

The return loss, VSWR and gain for the designed antenna is shown in Fig 6.7. (a, b, c, d) respectively. The discussed design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range. These result will be used in UWB application.

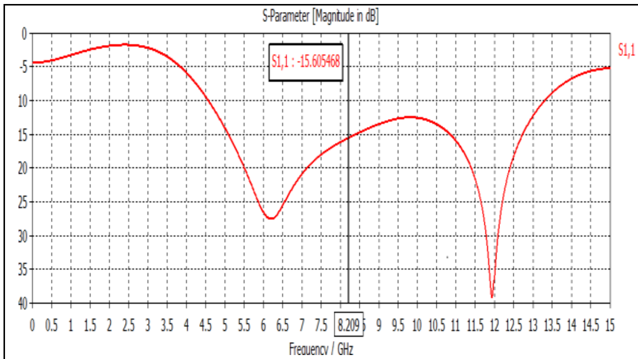


Fig.6.7 (a) Return Loss = -10.37 dB

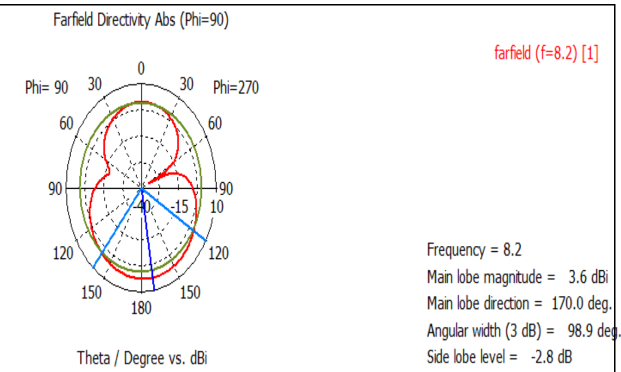


Fig. 6.7(b) Directivity = 3.63 dB

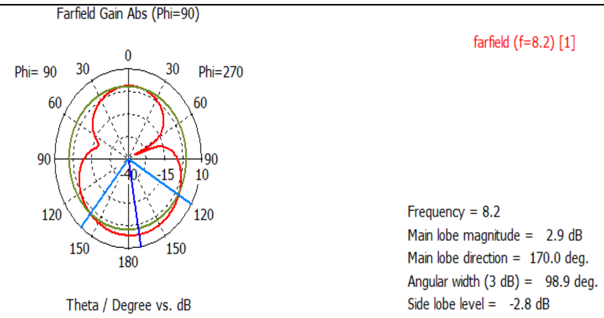


Fig.6.7(c) Gain =2.89 dB

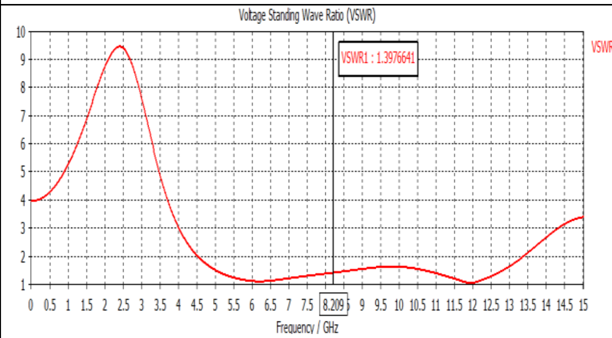


Fig6.7.(d) VSWR =1.39

The position of deep curve in return loss plot at resonating frequency 6.22GHz, 8.2GHz and 11.29 GHz with Return Loss -27.58dB , -15.6dB ,-38.63 dB and with VSWR 1.08, 1.39,1.26

6.2.4 For Different variation of parameter Return Loss, VSWR, gain and Band width w ere changed shown in below Tables.

a) If thickness of substrate is changed which led to change other parameter shown in table 6.8

Table 6.8 Substrate thickness changed

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss(dB)	VSWR
1.	1.4	4.4	4.88-13.17	8.29	-12.36	1.63
2	1.58	4.4	4.74-13.17	8.43	-14.26	1.48
3	1.65	4.4	4.7-13.17	8.43	-14.81	1.44
4	**1.7**	**4.4**	**4.7-13.1**	**8.43**	**-15.07**	**1.42**

b) Simulated Result if Variation of thickness of substrate takes place .

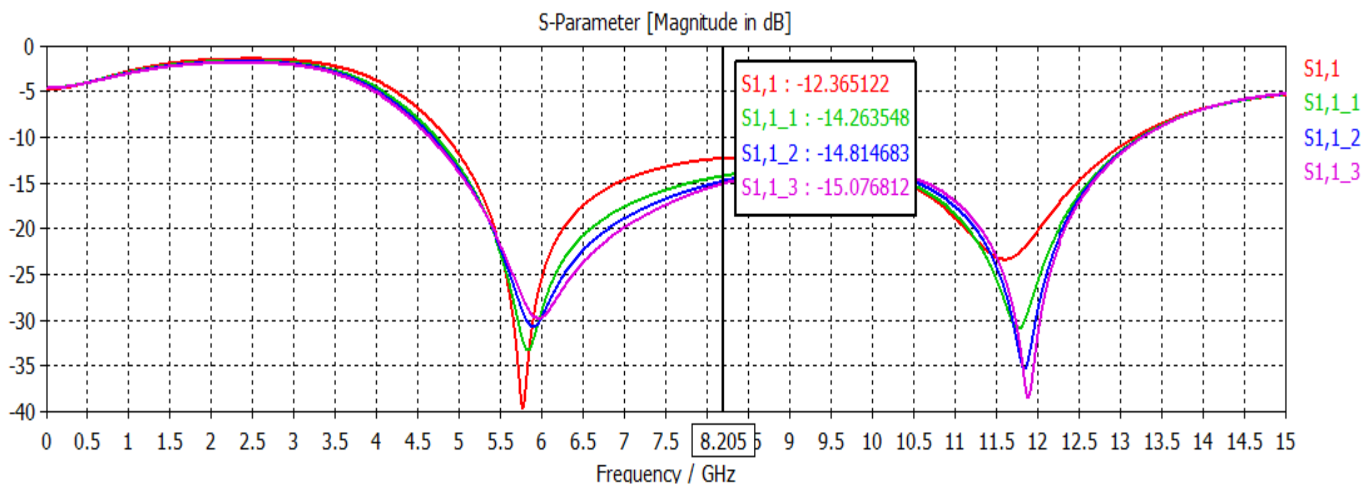
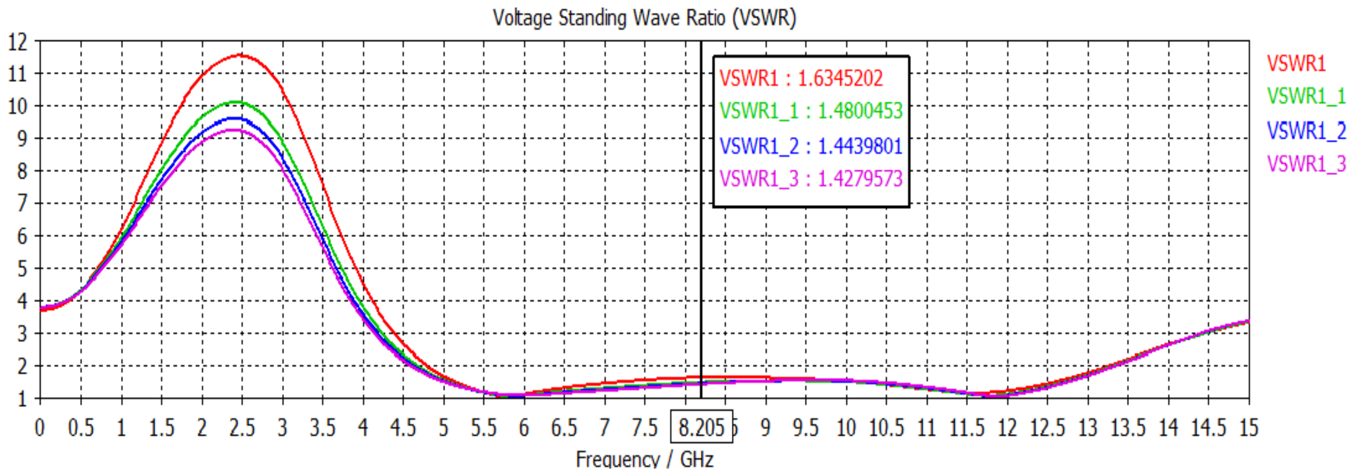


Fig. 6.8 Plot of Return Loss wtr h

Red Line – h = 1.4mm , Green Line – h = 1.58mm, Blue Line –h = 1.65mm, Purple Line – h = 1.7mm

This fig.6.7 shows as the the thickness of substrate is increasing the antenna achieve good return loss and VSWR is also get reduced due to which matching between feed line and patch can be done due which maximum power can be transmitted.

c)Simulated Result if thickness of substrate is changed with respect to VSWR



Red Line – h = 1.4mm , Green Line – h = 1.58mm, Blue Line –h = 1.65mm, Purple Line – h = 1.7mm

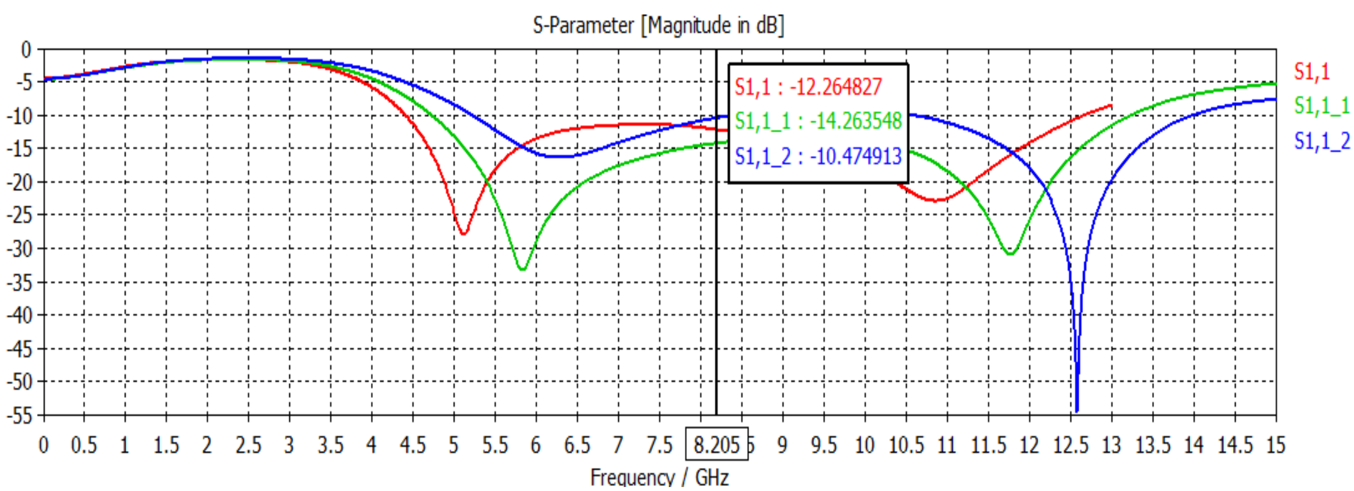
Fig. 6.9 Plot of VSWR

d)Table 6.9 If Lg is changed (Length of Partial Ground at Ws = 12mm)

Table 6.9 L_g Variation

No. of Iteration	Lg (mm)	Return Loss(dB)	VSWR	Directivity (dB)	Gain(dB)	Band Width(GHz)
1	3	-12.64	1.64	3.65	2.96	8.24
2	**4**	**-15.06**	**1.4**	**3.64**	**2.91**	**8.53**
3	5	-10.47	1.8	3.78	2.93	3Ghz, 7.31 GHz

e) Return Loss Plot variation of L_g:-



Red Line – L_g= 3mm, Green Line- L_g= 4mm, Blune line – L_g = 5mm

Fig. 6.10 Return Loss Plot wrt L_g

f) VSWR Plot variation of L_g

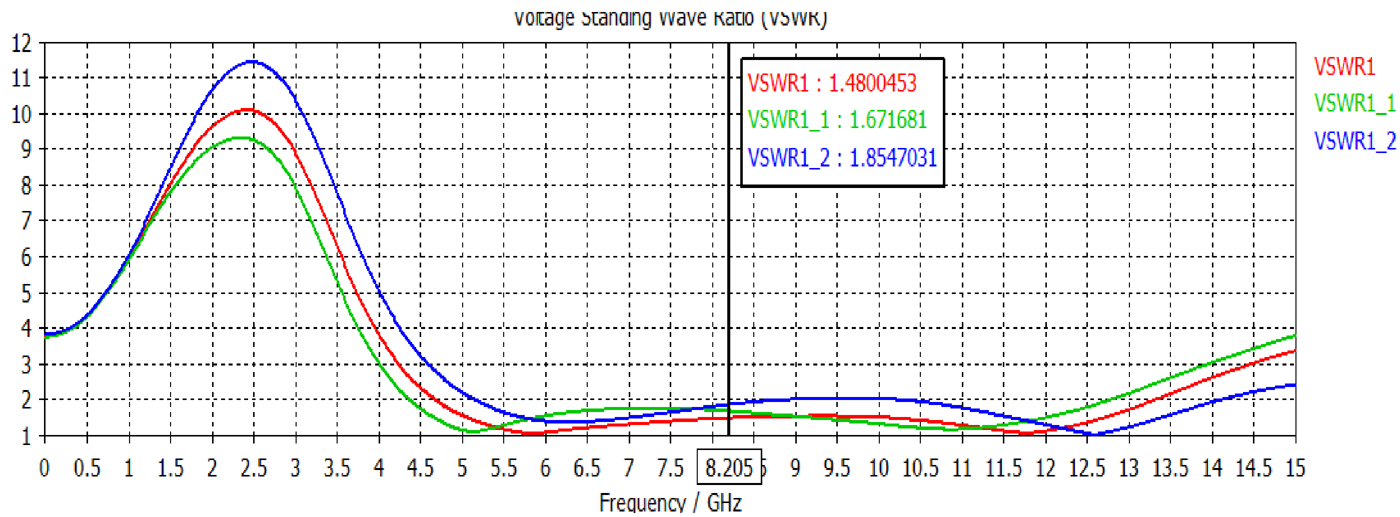


Fig. 6.11 VSWR Plot wrt L_g

The optimize value due to variation of L_g is obtained a bandwidth 8.53 Ghz and VSWR = 1.4

6.2.5 RLC circuit values and model Simple Circular MPA

The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Fig. 6.12

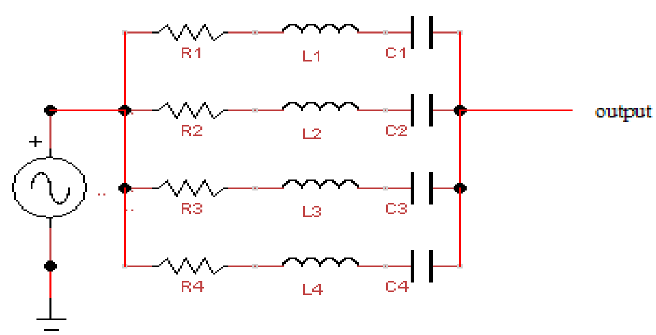


Fig. 6.12 Equivalent Model

The Parameter were calculated with the help of Z_0 =50 ohm= $\sqrt{(L/C)}$, and the parameter were shown in table 6.10.

Table 6.10 RLC value for designed antenna

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	4.7	R1= 12.67	L1= 1.6	C1= 0.67
2	5.9	R2= 15.97	L2= 1.3	C2= 0.53
3	11.88	R3= 8.98	L3= 0.67	C3= 0.26
4	12.34	R4= 10.11	L4= 0.64	C4= 0.25

6.3 Design of Circular Patch with Circular Slit

The third design is circular patch antenna with partial ground plane structure . FR-4 Epoxy dielectric substrate is used with εr= 4.4. Characteristic impedance of 50 ohm microstrip feedline is used to fed to patch. . The results show that the proposed antenna has the bandwidth (vswr=1.29) bandwidth of 8.1 GHz comes under the UWB band therefore the this is a good antenna to be used for the UWB application. Partial ground plane is used here. In order to increase the bandwidth as a ground plane.

6.3.1 Dimension of Proposed antenna:-

Resonating Frequency	8.1 GHz
Length of Feed line(L_f)	7mm
Width of Feed(W_f)	2mm
Length of Substrate(L_s)	18mm
Width of Substrate(W_s)	12mm
Radius of Circular Patch(a)	5mm
Thickness of Substrate(h)	1.58mm
Thickness of Patch(Mt)	0.07mm
Outer Slit Radius (b)	2mm
Inner Slit Radius (c)	1mm

Table 6.8 Parameter and dimension of Antenna

6.3.2 Model of Circular patch with Slit

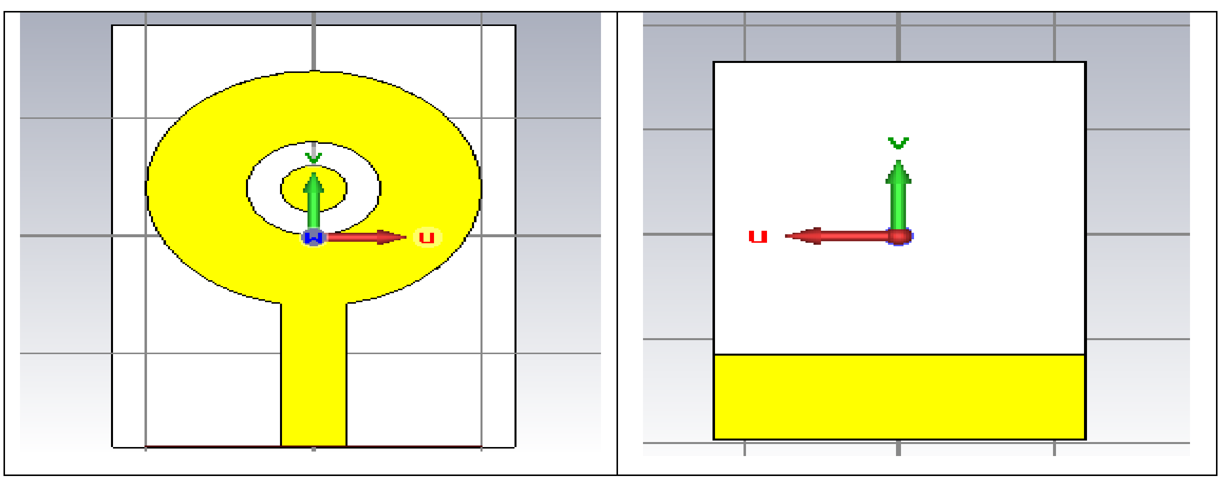


Fig 6.13 Model of Circular Patch with circular slit feed line front and back view

6.3.3 Results and discussion

The return loss, VSWR and gain for the designed antenna is shown in Fig 6.14. (a, b, c, d) respectively. The discussed design achieves the return loss of -17.88 dB and the bandwidth of 8.2 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.29 < 2 for entire bandwidth range. These result will be used in UWB application.

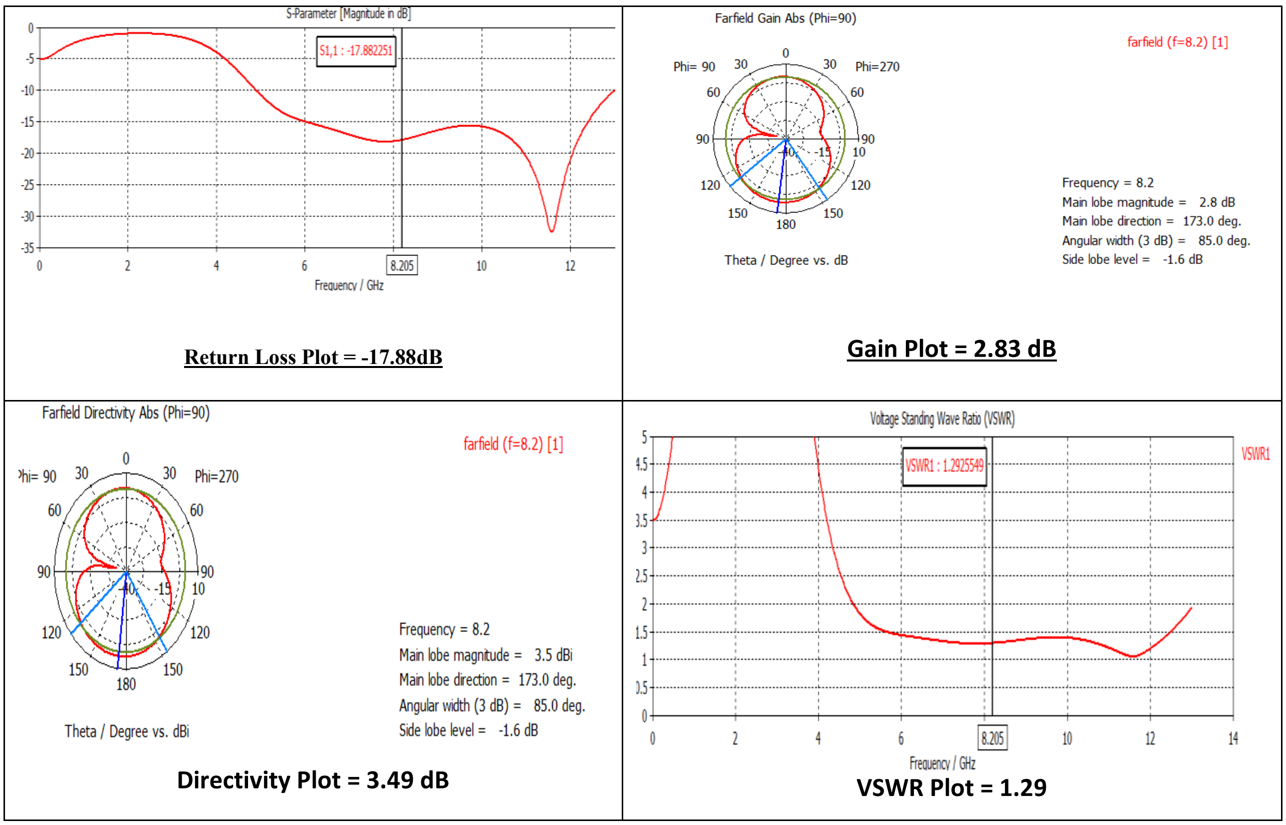


Fig. 6.14 Pattern of Return Loss, VSWR, Gain, Directivity of Simple Circular Patch f_r = 8.2 Ghz

The position of deep curve in return loss plot at resonating frequency7.74 GHz, 8.2GHz and 11.57 GHz with Return Loss -18.18dB , -32.07 ,-38.63 dB and with VSWR 1.29, 1.29,1.04

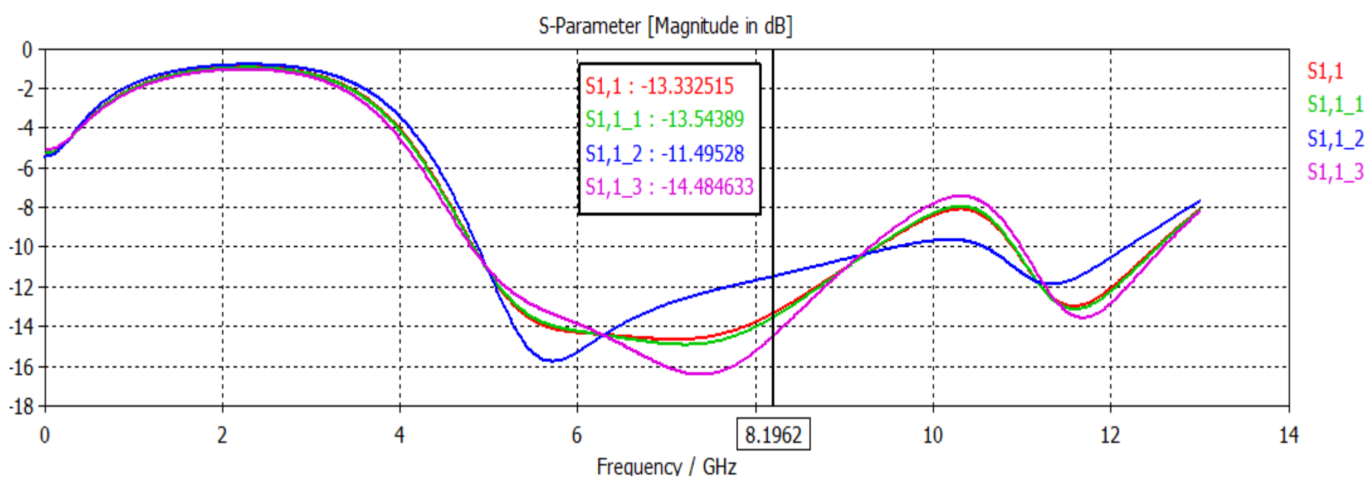
6.3.4 For Different variation of parameter Return Loss, VSWR, gain and Band width w ere changed shown in below Tables

a) If substrate thickness is changed at constant length of ground L_g= 4mm, f_r= 8.2 GHz .

Table 6.9 Variation of thickness of substrate

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss(dB)	VSWR
1.	1.4	4.4	4.8-9.4, 10.4-12.16	4.6, 1.76	-11.48	1.726
2	1.58	4.4	4.8-9.3, 9.21-10.92	4.5, 1.71	-13.3	1.55
3	1.6	4.4	4.8-9.3, 10.9-12.53	4.5, 1.63	-13.5	1.53
4	**1.7**	**4.4**	**4.8-9.3, 11.0-12.5**	**4.8, 1.5**	**-14.4**	**1.46**

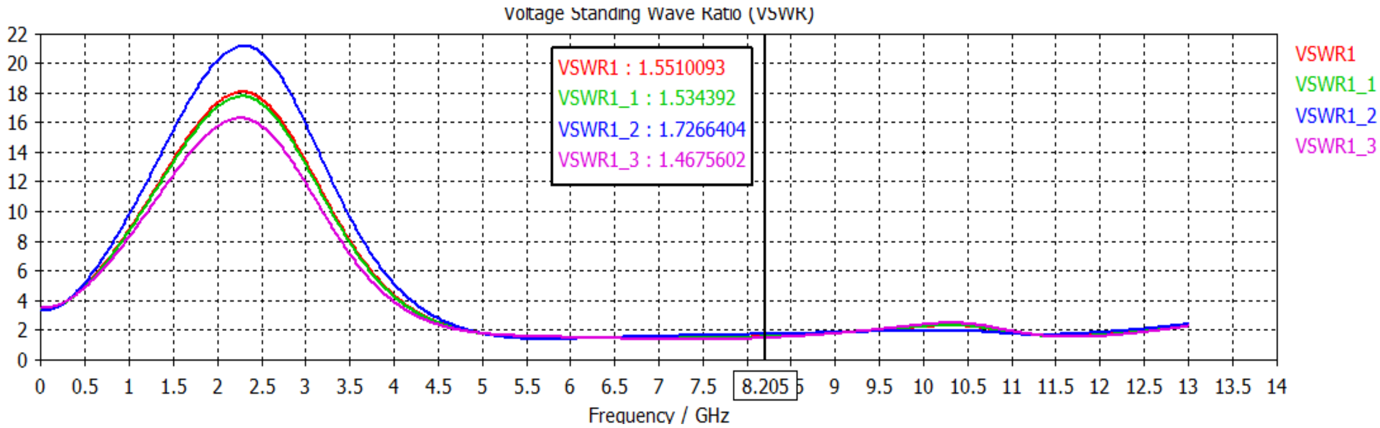
b) Simulated Return Loss Plot on Variation of h



Red Line – h = 1.58mm , Green Line – h = 1.6 mm, Blue Line –h = 1.4 mm, Purple Line – h = 1.7mm

Fig. 6.15 Return Loss Plot wrt h

c)Simulated VSWR Plot on Variation of h



Red Line – h = 1.58mm , Green Line – h = 1.6 mm, Blue Line –h = 1.4 mm, Purple Line – h = 1.7mm

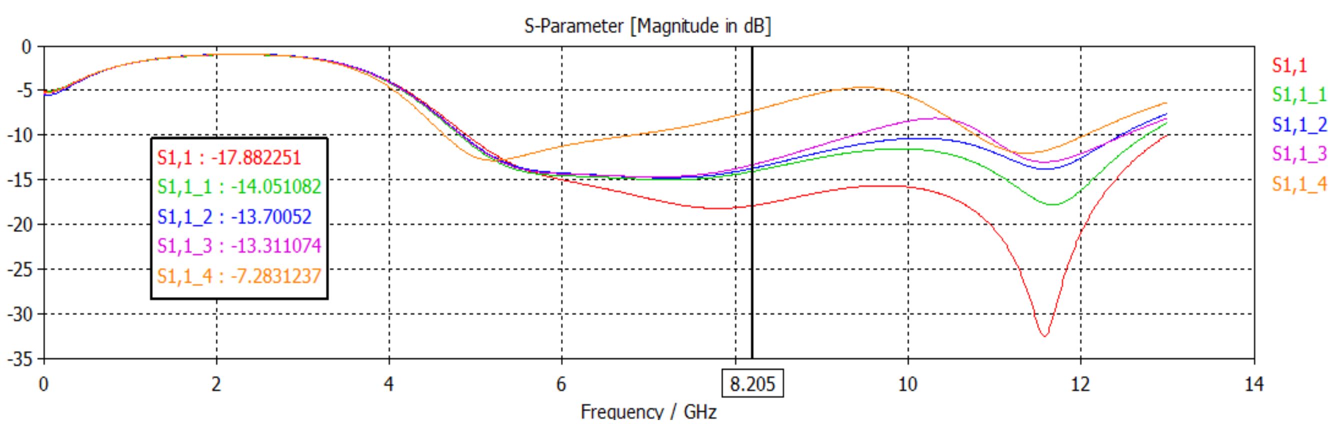
Fig. 6.16 VSWR Plot wrt h

d)If the inner and outer radius of slit i.e b, c value to obtain an optimize frequency band f_r= 8.2

Table 6.10 Variation Slit dimension

Sl.No	Outer Slit Radius b(mm)	Inner Slit Radius c(mm)	Return Loss (dB)	VWSR	Band Width(GHz)
1	**2**	**1**	**-17.88**	**1.29**	**8.1**
2	3	1	-14.0	1.49	7.93
3	3	2	-13.7	1.52	7.7
4	3	2.5	-13.31	1.55	4.6, 1.7
5	4	2	-7.28	2.5	1.4, 1.3

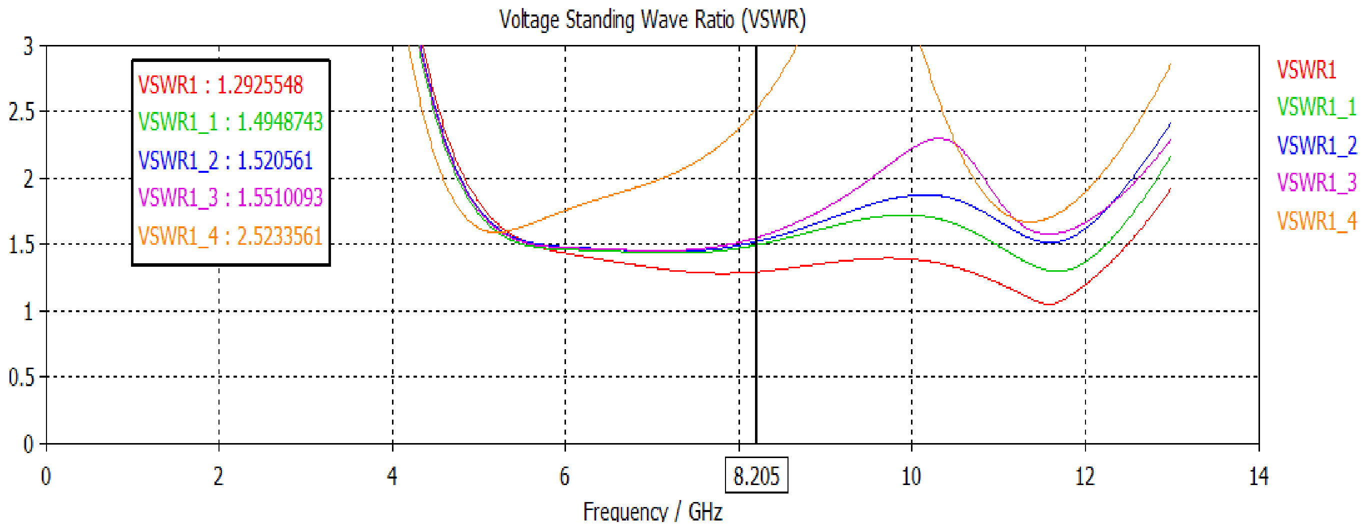
e)Simulated Return Loss Plot on Variation of b &c



S1,1(b= 2, c=1), S1,1_1 (3, 1), S1,1_2(3,2), S,1,1_3(3,2.5), S1,1_4(4,2)

Fig. 6.17 Return Loss Plot wrt to slit dimension

f)Simulated VSWR Plot on Variation of b & c



S1,1(b= 2, c=1), S1,1_1 (3, 1), S1,1_2(3,2), S,1,1_3(3,2.5), S1,1_4(4,2)

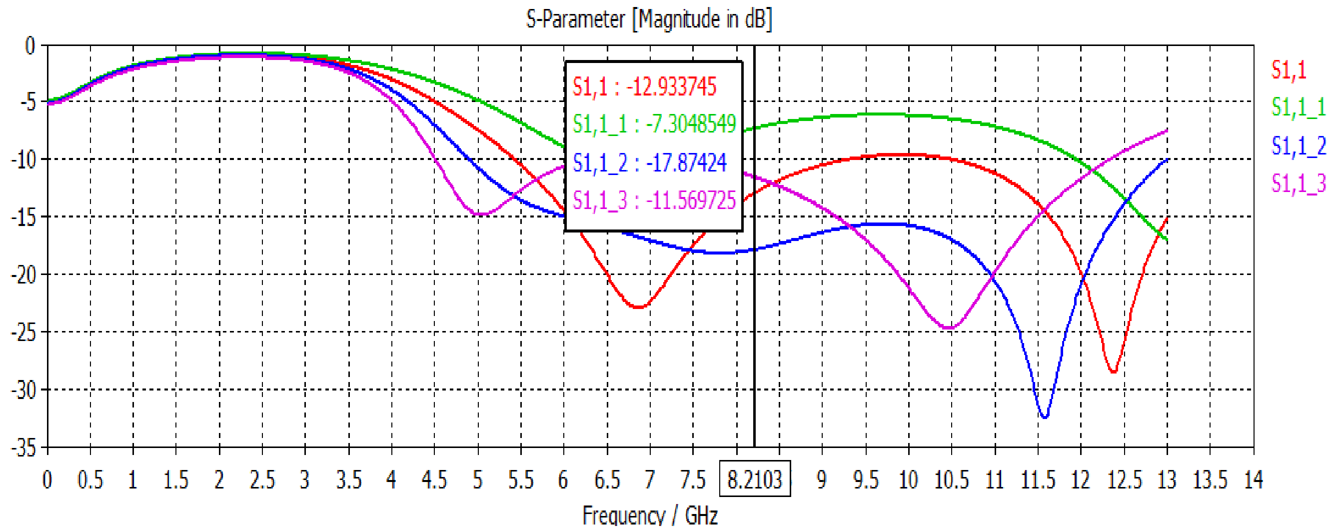
Fig. 6.18 VSWR Plot wrt dimension of slit

g)If L_g is varied at constant Slit Dimension:-

Table 6.11Variation of L_g

Sl.No.	**L_g (mm)**	**Return Loss(dB)**	**VSWR**	**Directivity(dB)**	**Gain(dB)**	**Band Width(GHz)**
1	3	-11.35	1.7	3.49	2.89	2.4, 3.87
2	**4**	**-17.88**	**1.29**	**3.49**	**2.83**	**8.1**
3	5	-12.95	1.58	3.58	2.83	3.72, 2.65
4	6	-7.31	2.51	3.72	2.87	0.62, 1

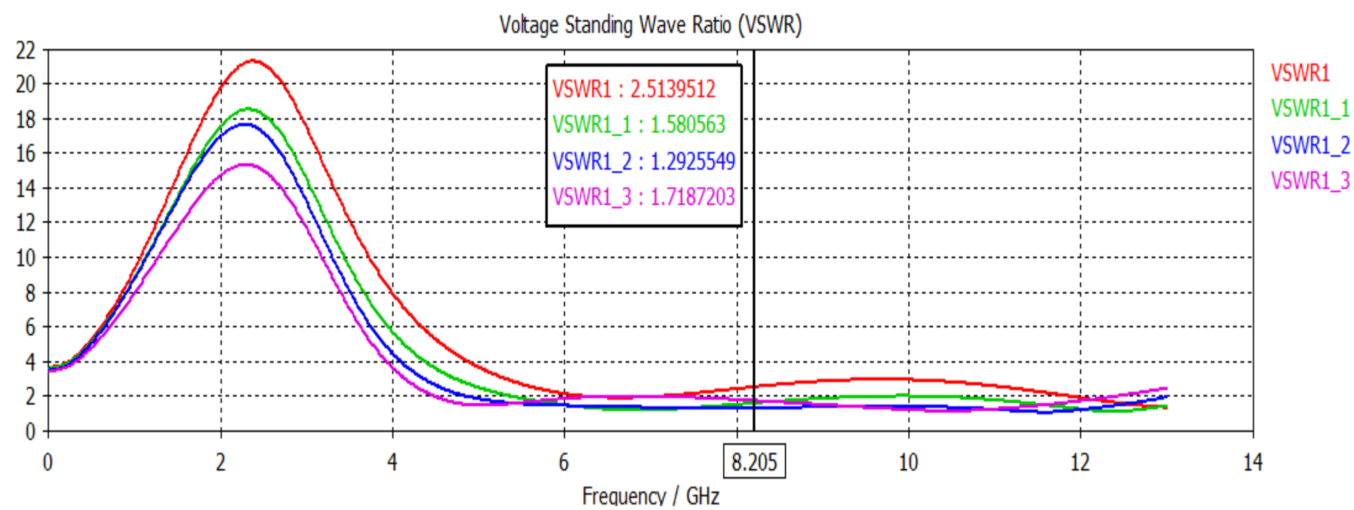
h) Simulated Return Loss Plot on Variation L_g



S1,1 (L_g = 5), S1,1_2(L_g= 4), S1,1_1(L_g= 6), S1,1_3(L_g= 3)

Fig. 6.19 Return Loss Plot wrt L_g

i)Simulated VSWR Plot on Variation of L_g



S1,1 (L_g = 5), S1,1_2(L_g= 4), S1,1_1(L_g= 6), S1,1_3(L_g= 3)

Fig. 6.20 VSWR Plot wrt L_g

6.3.5 RLC circuit values Simple Circular MPA with Circular Slit

The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Fig. 6.21

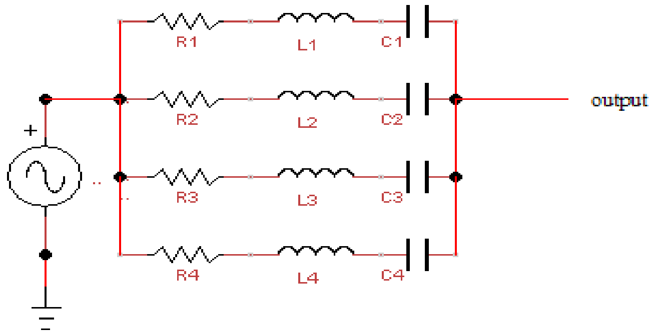


Fig. 6.21 Equivalent RLC Model of Proposed Antenna

The Parameter were calculated with the help of Z_0 =50 ohm= $\sqrt{(L/C)}$, and the parameter were shown in table 6.12

Table 6.12 RLC value for designed antenna

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	4.8	R1= 47.24	L1= 1.65	C1= 0.66
2	7.7	R2= 8.48	L2= 1.03	C2= 0.41
3	10.5	R3= 9	L3= 0.75	C3= 0.3
4	12	R4= 8.26	L4= 0.66	C4= 0.26

6.4 Design 3 on Extended Circular Patch with Rectangular Stub

The antenna geometry consist of a half circular patch which is extended an extra rectangular length. Antenna is fabricated on FR-4 Epoxy material and microstrip feed line is used for feeding. A circular shape partial ground plane is used with an elliptical notch just below the feedline. The simulation results show that the antenna fulfils the requirement of UWB antenna.

6.4.1 Dimension of Proposed antenna:-

Resonating Frequency	7.0 GHz
Length of Feed line(L_f)	10 mm
Width of Feed(W_f)	3.058 mm
Length of Substrate(L_s)	30 mm
Width of Substrate(W_s)	27 mm
Radius of Circular Patch(a)	9.5 mm
Thickness of Substrate(h)	1.5mm
Thickness of Patch(Mt)	0.07mm
Width of Stub (W_s)	15 mm
Length of Stub (L_s)	5 mm

Table 6.13 Parameter and dimension of Antenna

6.4.2 Model of Extended Circular Patch

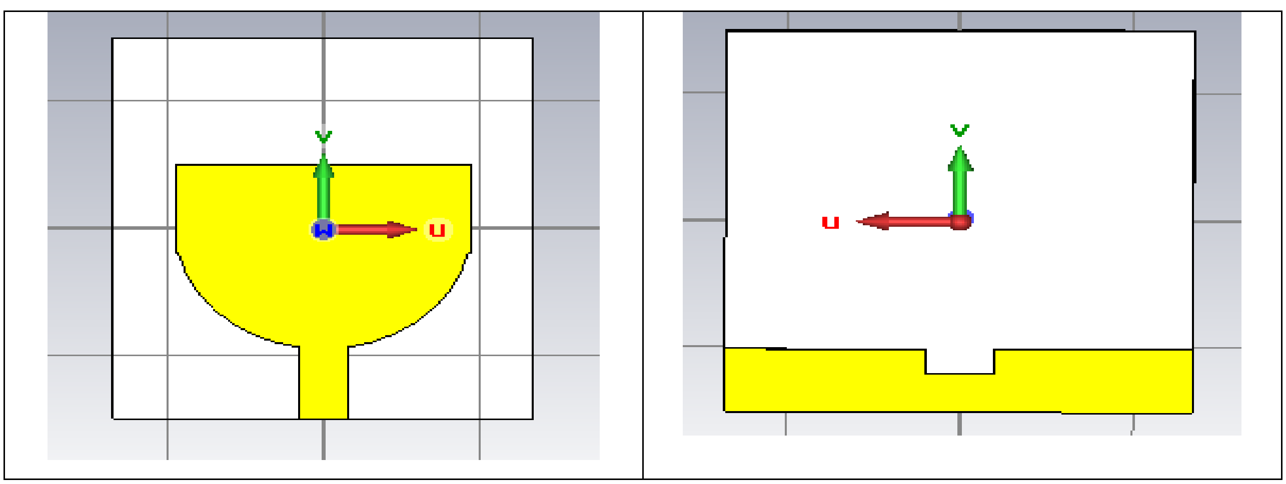


Fig. 6.22 Front and back view of Proposed Antenna

6.4.3 Results and discussion

\The return loss, VSWR and gain for the designed antenna is shown in Fig 6.21. (a, b, c, d) respectively. The discussed design achieves the return loss of -14.05dB and the bandwidth of 10.0 GHz (3.98- 13.98GHz) and corresponding VSWR is 1.48 < 2 for entire bandwidth range. These result will be used in UWB application

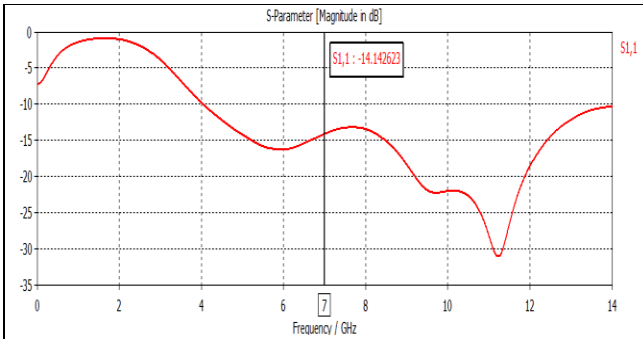


Fig. 6.20(a)**Return Loss= -14.05 dB**

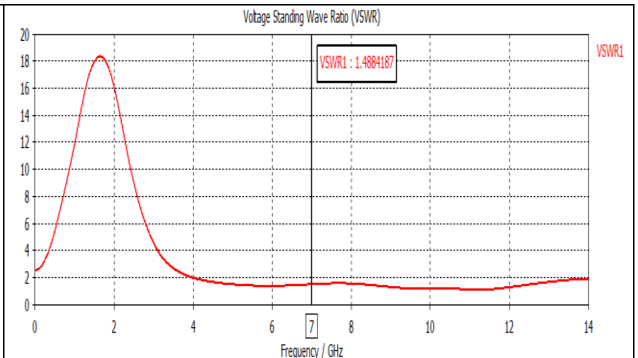


Fig. 6.20(b)**VSWR = 1.48**

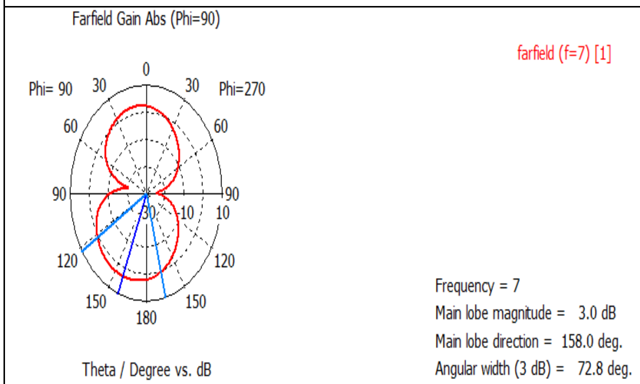


Fig. 6.20(c)Gain = 2.98 dB

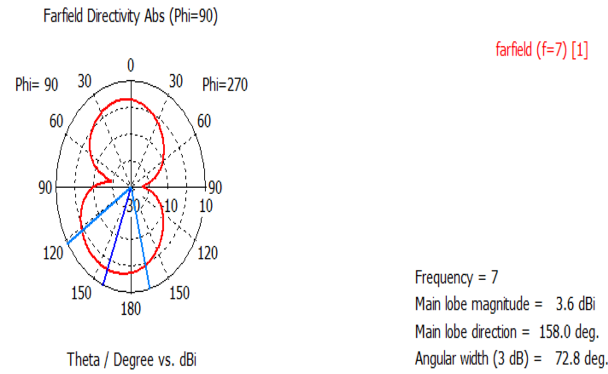


Fig. 6.20(d)**Directivity= 3.54dB**

Fig 6.23 Pattern of Return Loss, VSWR, Gain, Directivity of Simple Circular Patch f_r = 7.0 Ghz

The position of deep curve in return loss plot at resonating frequency 6.00GHz, 9.72GHz and 11.82 GHz with Return Loss -15.48dB , -35.16dB ,-24.48dB and with VSWR 1.4, 1.03,1.12

6.4.4 For Different variation of parameter Return Loss, VSWR, gain and Band width were changed shown in below Tables

a) If thickness of substrate is varied at constant Ground L_g= 4mm, f_r= 7.0 GHz

Table 6.14 Variation of h

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss(dB)	VSWR
1.	1.4	4.4	3.95-7.87, 8.25-13.16	3.92, 4.91	-12.65	1.6
2	1.5	4.4	3.95-13.067	9.11	-13.25	1.55
3	1.55	4.4	3.95-13.12	9.17	-13.5	1.53
4	1.6	4.4	3.98-13.15	9.17	-13.75	1.51
5	1.7	4.4	3.98-13.58	9.9	14.0	1.49
6	**1.8**	**4.4**	**3.98-13.98**	**10**	**-14.5**	**1.48**

b) Return Loss Plot on Variation of h

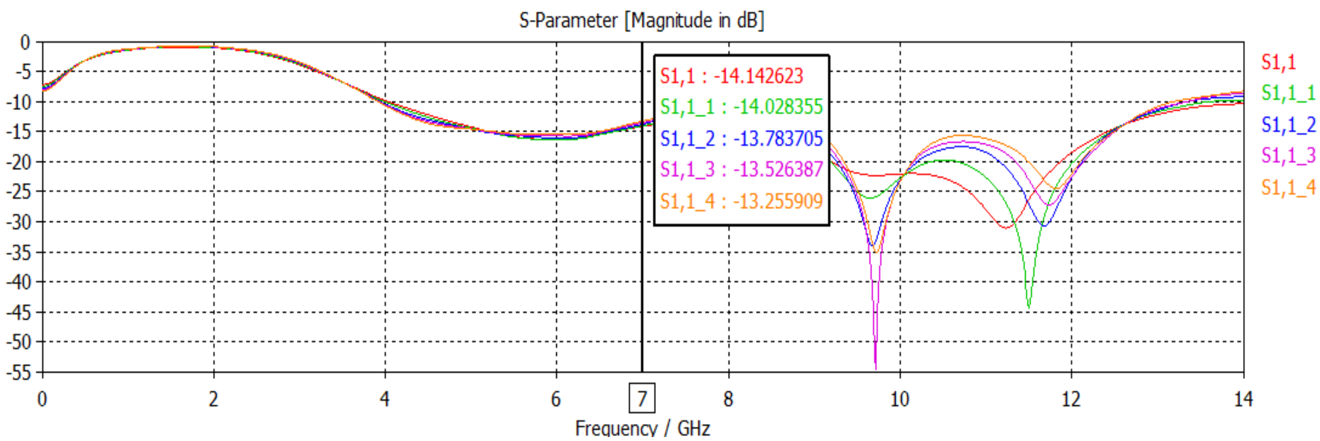


Fig. 6.24 Return Loss Plot wrt h

c) VSWR Plot on Variation of h

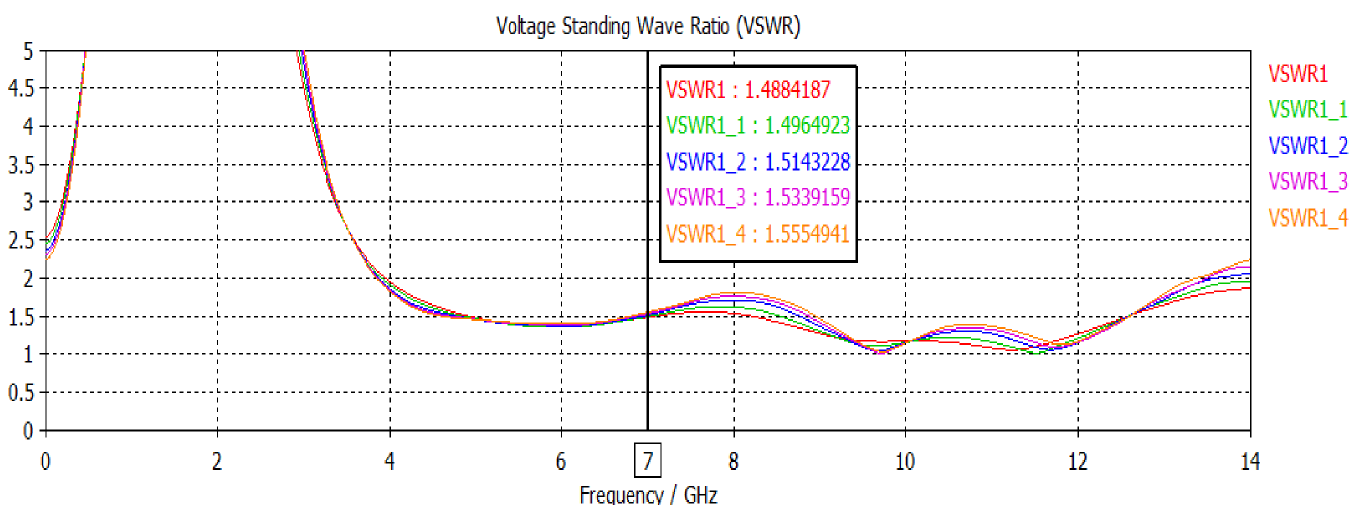


Fig. 6.25 VSWR Plot wrt h

d)If L_g is varied at constant h = 1.8mm

Table 6.15 Variation of L_g

Sl. No.	L_g(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	Band Width(GHz)
1	4	-9.75	**1.96**	3.55	2.94	3.2, 4.95
2	**5**	**-14.05**	**1.48**	**3.54**	**2.98**	**10**
3	6	-14.9	**1.43**	3.56	3.014	7.29
4	7	-8.95	**2.1**	3.62	3.01	0.72

e) Simulated Return Loss Plot effect of L_g

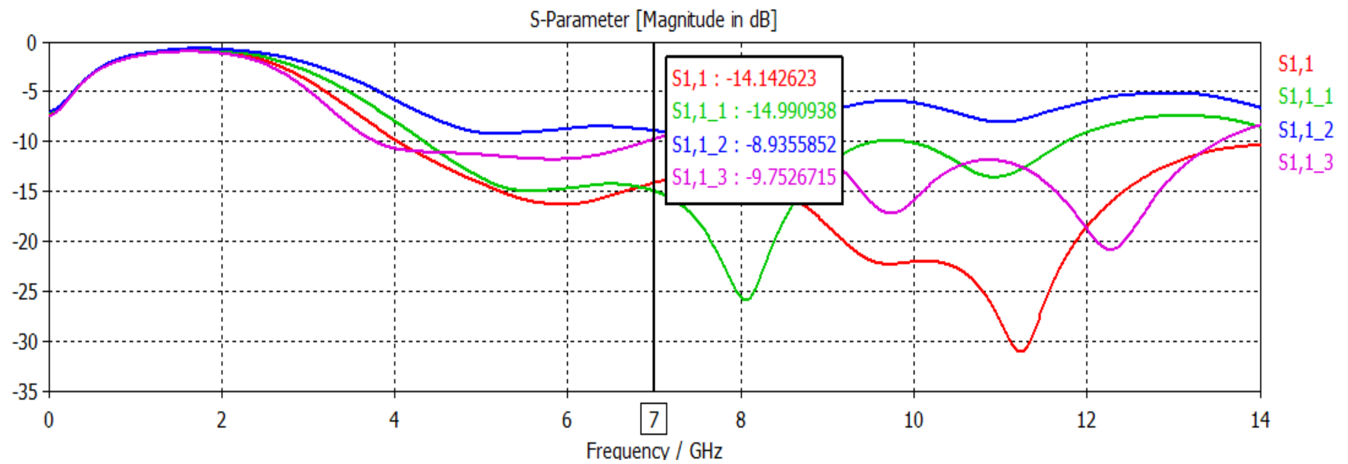


Fig. 6.26 Return Loss Plot wrt L_g

g)Simulated VSWR Plot Effect of Lg

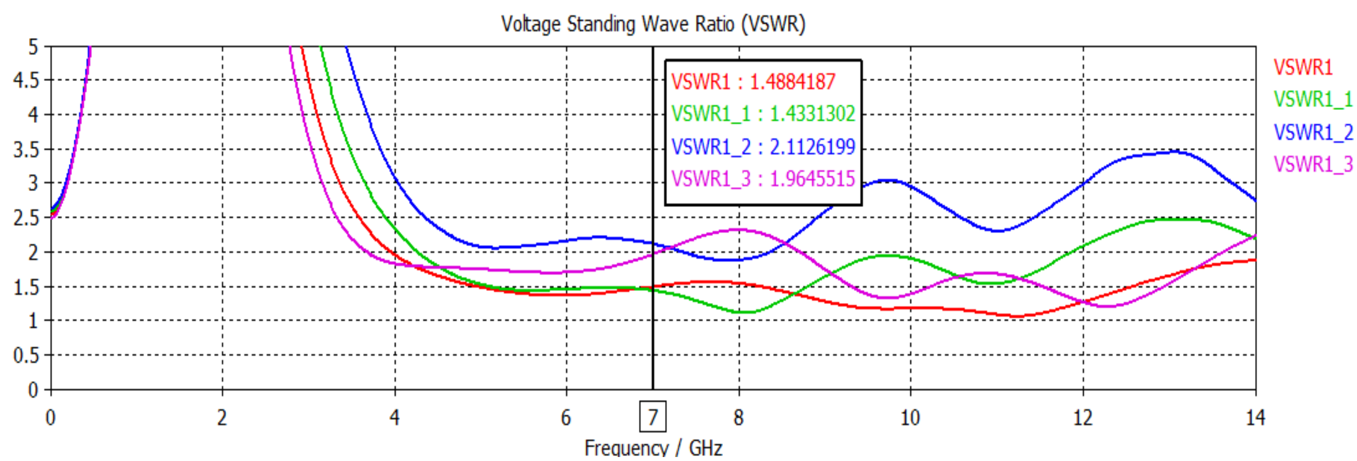


Fig. 6.27 VSWR Plot wrt L_g

h) If Notch Width on Ground Plane(W_N) is varied.

Table 6.16 Variation of W_N

Sl.No.	W_N(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	BW(GHz)
1	3	-16.3	1.36	3.53	2.97	9.2
2	**4**	**-14.05**	**1.48**	**3.54**	**2.98**	**10**
3	5	-11.9	1.67	3.54	2.96	8.7

i)Simulated Return loss Plot on Variation of W_N

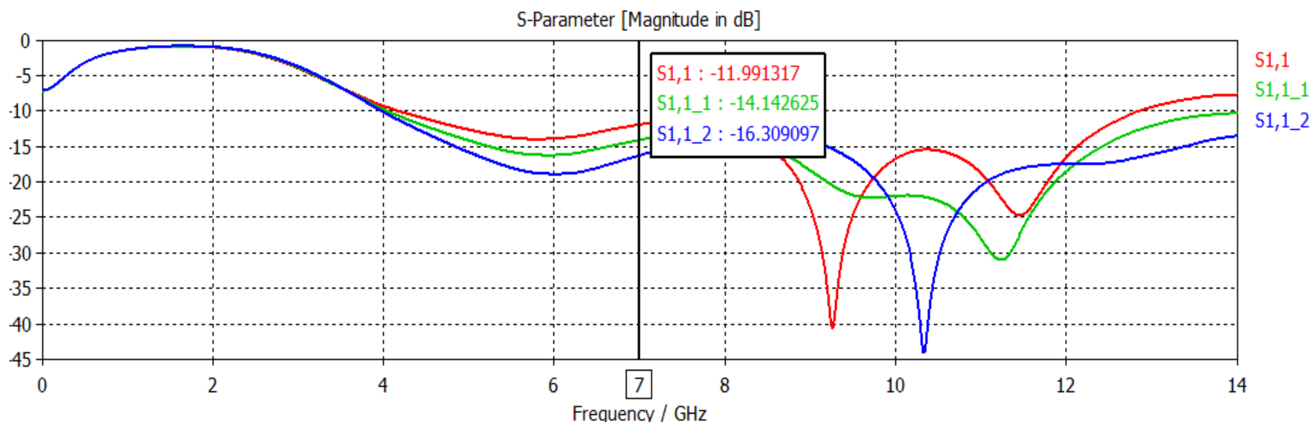


Fig. 6.28 Return Loss Plot wrt W_N

j)Simulated VSWR Plot on Variation on W_N

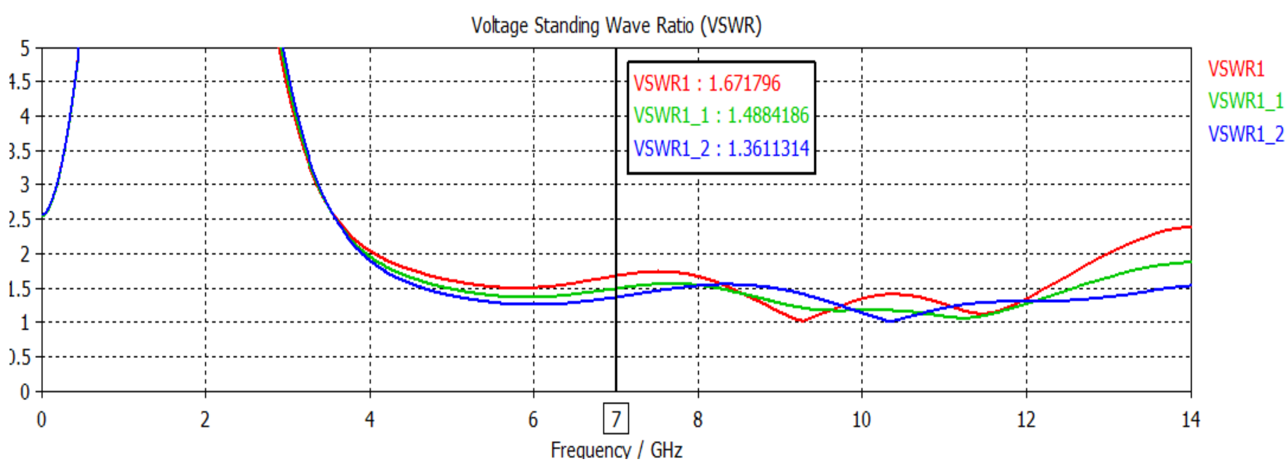


Fig. 6.29 VSWR Plot wrt W_N

6.4.5 RLC circuit values Extended Circular MPA with Notch

The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Fig. 6.30

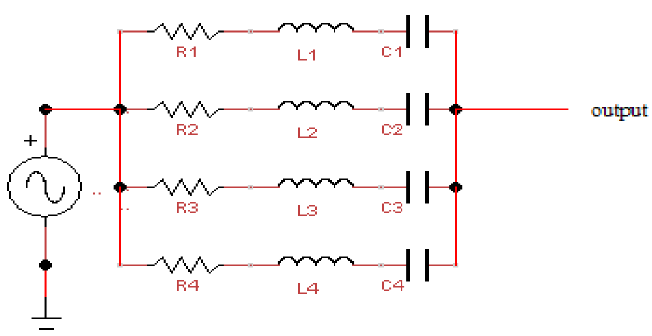


Fig. 6.30 Equivalent RLC Model of Proposed Antenna

The Parameter were calculated with the help of Z_0 =50 ohm= $\sqrt{(L/C)}$, and the parameter were shown in table 6.17

Table 6.17 RLC value for designed antenna

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	4.0	R1= 11.4	L1= 1.9	C1= 0.79
2	6.04	R2= 5.79	L2= 1.32	C2= 0.53
3	9.39	R3= 12.65	L3= 0.84	C3= 0.84
4	11.2	R4= 6.7	L4= 0.71	C4= 0.28
5	13.84	R5= 6.42	L5 = 0.57	C5= 0.23

6.5 Design of Extended Circular MPA with Stub and Circular Slit

The antenna geometry consist of a half circular patch which is extended an extra rectangular length and circular slit . Antenna is fabricated on FR-4 Epoxy material and microstrip feed line is used for feeding. A circular shape partial ground plane is used with an elliptical notch just below the feedline. The simulation results show that the antenna fulfils the requirement of UWB antenna.

6.5.1 Dimension of Proposed Antenna

Resonating Frequency	7.0 GHz
Length of Feed line(L_f)	10 mm
Width of Feed(W_f)	3.058 mm
Length of Substrate(L_s)	30 mm
Width of Substrate(W_s)	27 mm
Radius of Circular Patch(a)	9.5 mm
Thickness of Substrate(h)	1.5mm
Thickness of Patch(Mt)	0.07mm
Width of Stub (W_{stub})	18.82 mm
Length of Stub (L_{stub})	7 mm
Outer Slit Radius(b)	3 mm
Inner Slit Radius(c)	2 mm
Width of Notch (W_N)	4 mm

Table 6.18 Dimension of designed antenna

6.5.2 Model of Extended Circular Patch with Stub and Slit

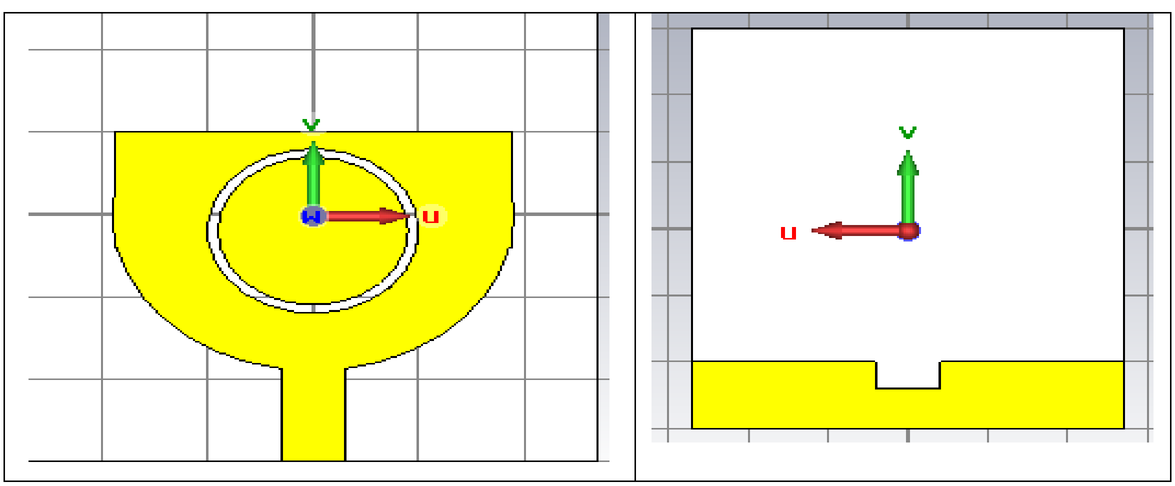


Fig 6.31 Front and back view of designed antenna

6.5. 3 Results and discussion

The return loss, VSWR and gain for the designed antenna is shown in Fig 6.32. (a, b, c, d) respectively. The discussed design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range. These result will be used in UWB application

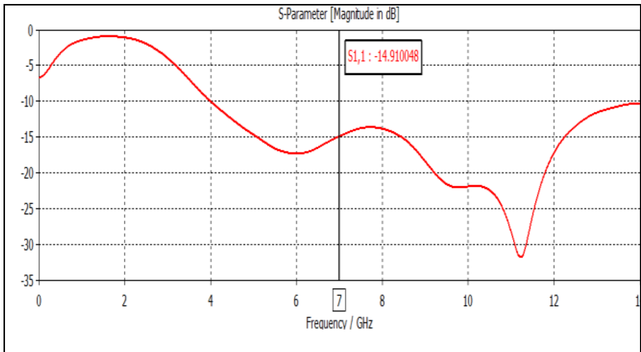


Fig. 6.29(a) Return Loss= -14.9 dB

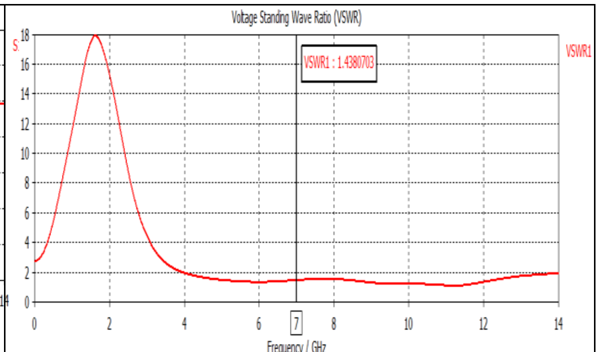


Fig. 6.29(b)VSWR = 1.43

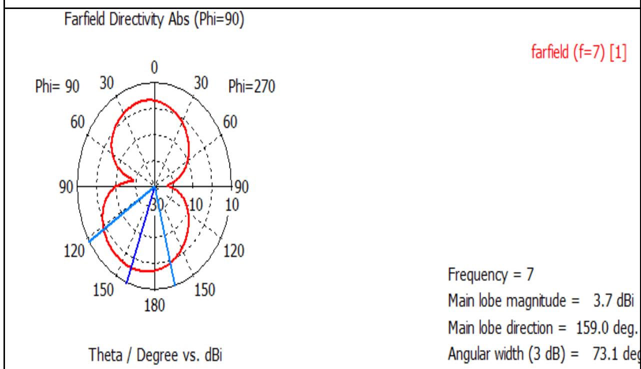


Fig. 6.29(c) Directivity = 3.67 dB

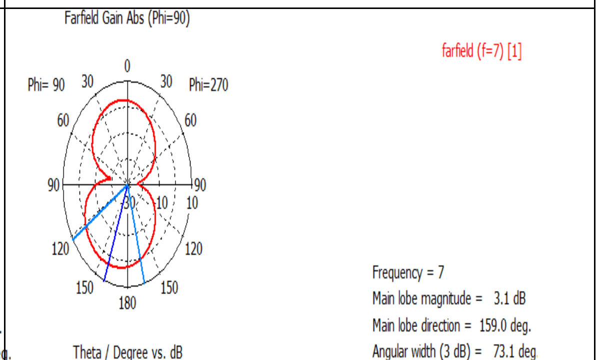


Fig. 6.29(d)Gain = 3.1 dB

Fig. 6.32 Pattern of Return Loss, VSWR, Gain, Directivity of Simple Circular Patch $f_r = 7.0$ Ghz

The position of deep curve in return loss plot at resonating frequency 6.0 GHz, 9.59GHz and 11.24 GHz with Return Loss -17.64dB , -21.9dB ,-31.73 dB and with VSWR 1.31, 1.17,1.05

6.5.4 For Different variation of parameter Return Loss, VSWR, gain and Band width w ere changed shown in below Tables

a)If thickness of substrate is varied at constant Ground L_g= 5mm, f_r= 7.0 GHz

Table 6.19 Variation of Substrate thickness

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss(dB)	VSWR
1(Purple)	1.55	4.4	3.91-13.0	9.02	-14.24	1.48
2 (Blue)	1.6	4.4	4.0-13.3	9.30	-14.36	1.47
3 (Green)	1.7	4.4	4.0-13.38	9.38	-14.7	1.44
4 (Red)	**1.8**	**4.4**	**3.98-14.0**	**10.02**	**-14.85**	**1.44**

b)Simulated Return Loss Plot on Variation of h

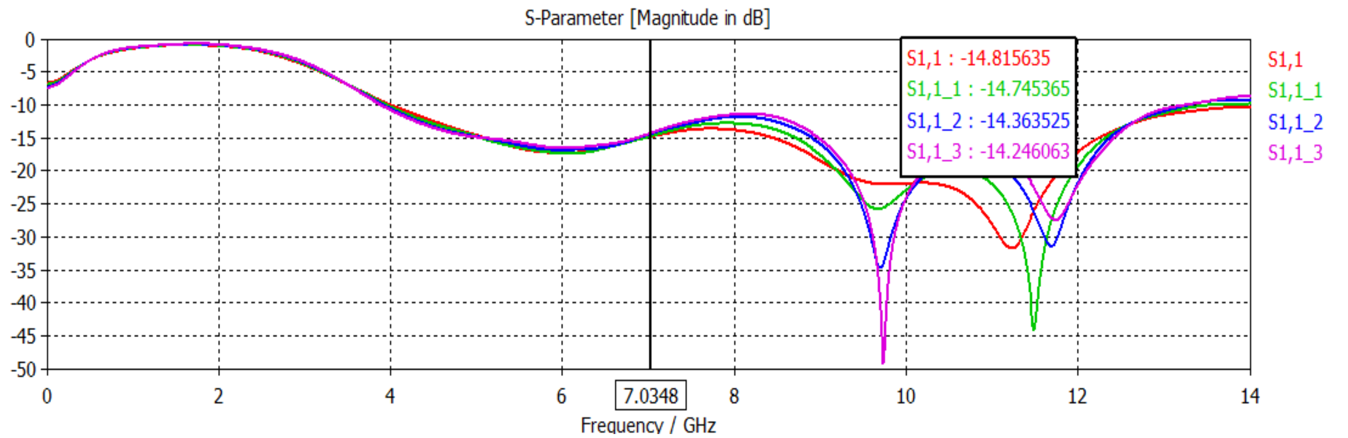


Fig.6.33 Retutn Loss plot wrt h

c)Simulated VSWR Plot on variation of h

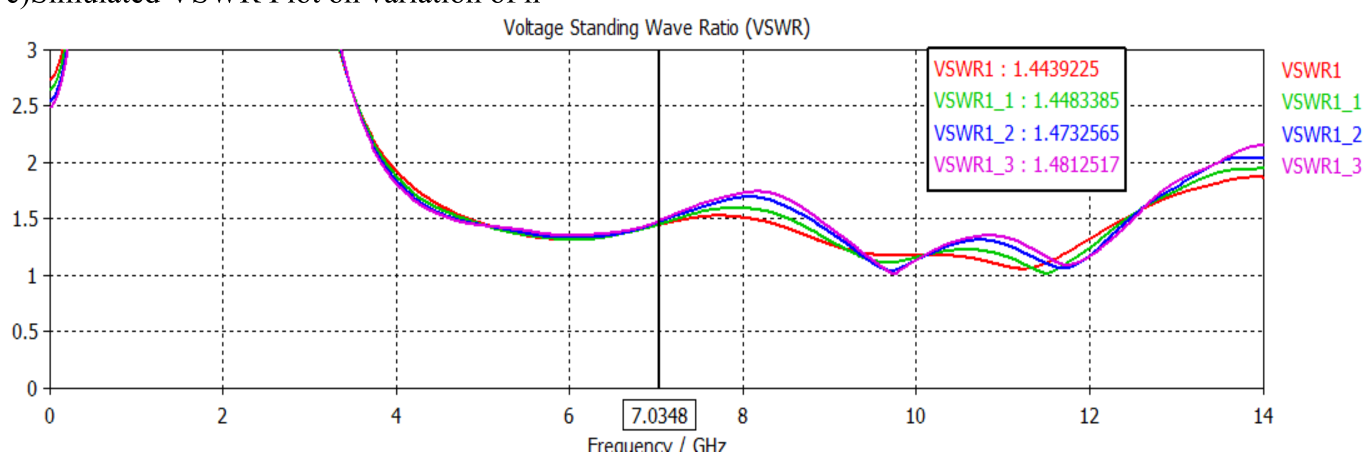


Fig.6.34 VSWR plot wrt h

d)If f Slit Radius is varied (b & c)

Table 6.20 Variation of Dimension of Slit

Sl.No	Outer Slit Radius b(mm)	Inner Slit Radius c(mm)	Return Loss (dB)	VWSR	Band Width(GHz)
1	4	3	-16.86	1.33	10.1
2	4	3.5	-17.28	1.31	10.1
3	4	2.5	-16.5	1.34	10.1
4	4	3.8	-18.37	1.27	3.6, 6.0
5	5	3.8	-10.19	1.8	3.1, 5.34
6	5	4.5	-6.3	2.86	2.7, 6.2
7	**3**	**2**	**-14.9**	**1.4**	**10.1**

e) Return Loss Plot on Variation of b &c

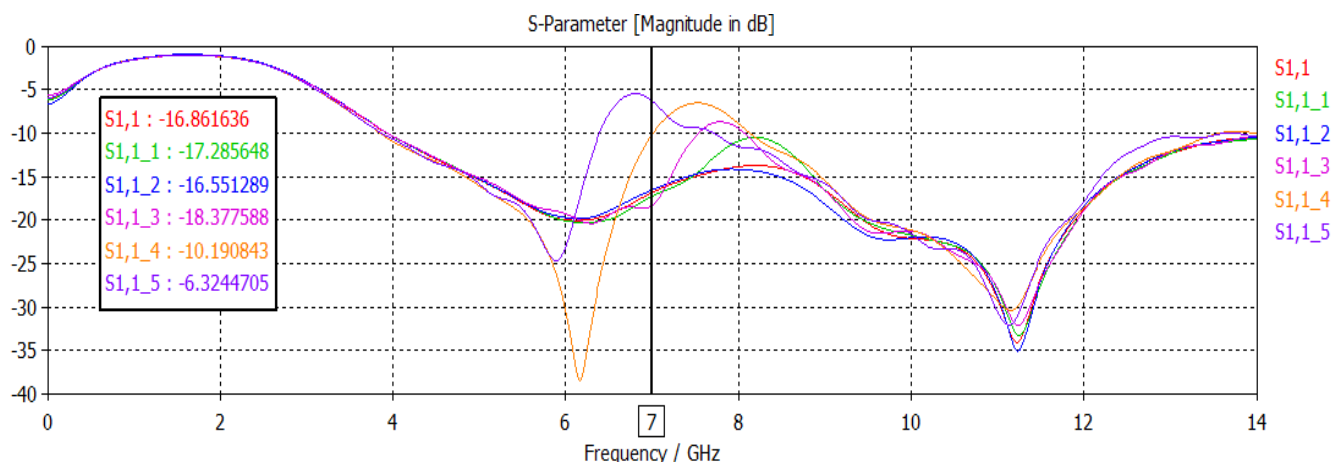


Fig.6.35 Retutn Loss plot wrt Slit dimension

f) VSWR Plot on Variation of b &c

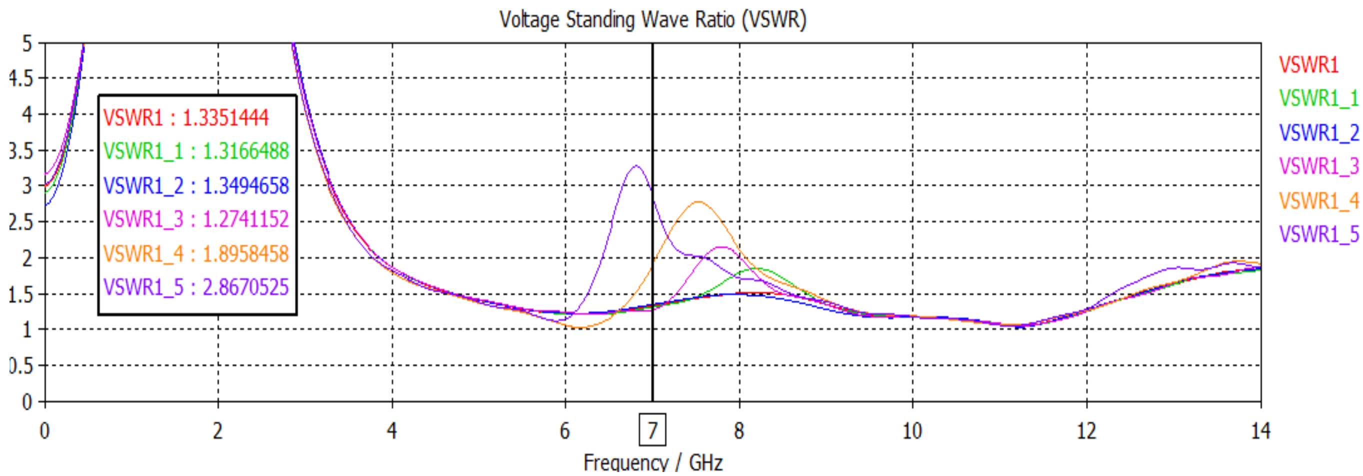


Fig.6.36VSWR plot wrt Slit Dimension

g)If L_g varied at constant Slit Dimension:-

Table 6.21 Variation of L_g

Sl.No.	L_g (mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	Band Width(GHz)
1	3	-7.63	2.4	3.67	2.968	0.82, 0.79,
2	**4**	**-10.26**	**1.88**	**3.673**	**3.052**	**3.27, 4.56**
3	**5**	**-14.9**	**1.4**	**3.671**	**3.10**	**10.1**
4	6	-14.78	1.44	3.67	3.12	5.31, 1.72

h)Simulated Return Loss Plot effect of L_g

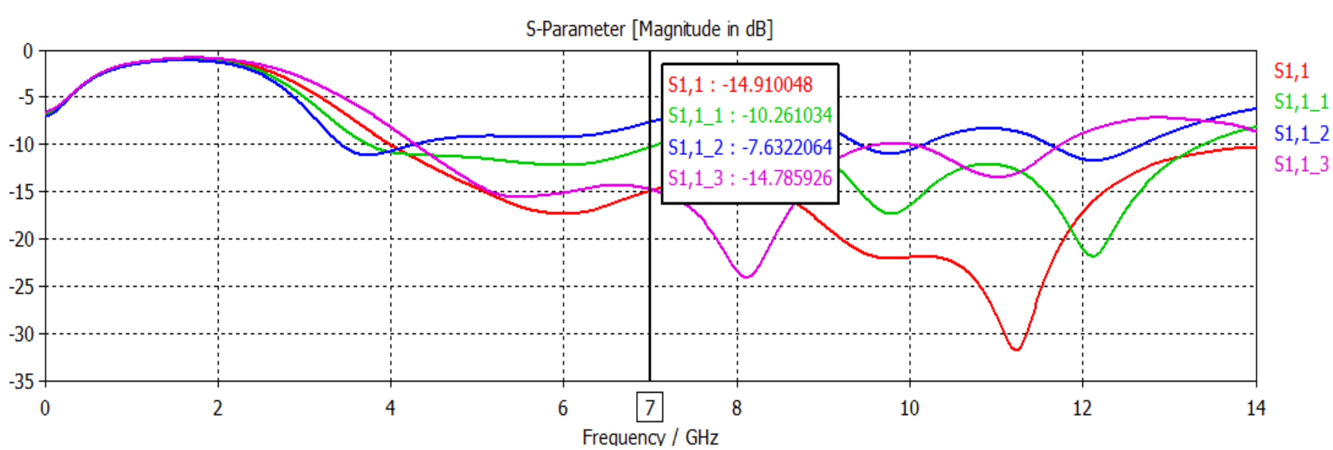


Fig.6.37 Retutn Loss plot wrt L_g

i)Simulated VSWR Plot Effect of Lg

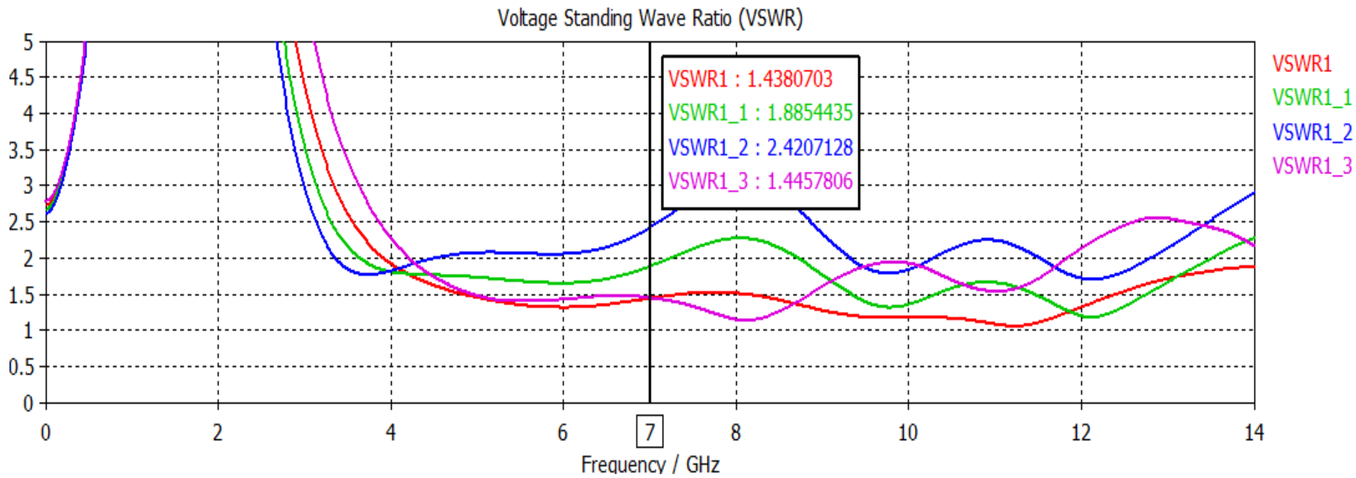


Fig.6.38 VSWR plot wrt L_g

j)If Notch Width is varied on Ground Plane(W_N)

Table 6.22Variation of W_N

Sl.No.	W_N(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	BW(GHz)
1	3	-17.33	1.31	3.65	3.09	10.1
2	4	-14.9	1.43	3.67	3.101	10.1
3	5	-12.6	1.61	3.66	3.08	8.6

k)Simulated Return loss Plot on Variation of W_N

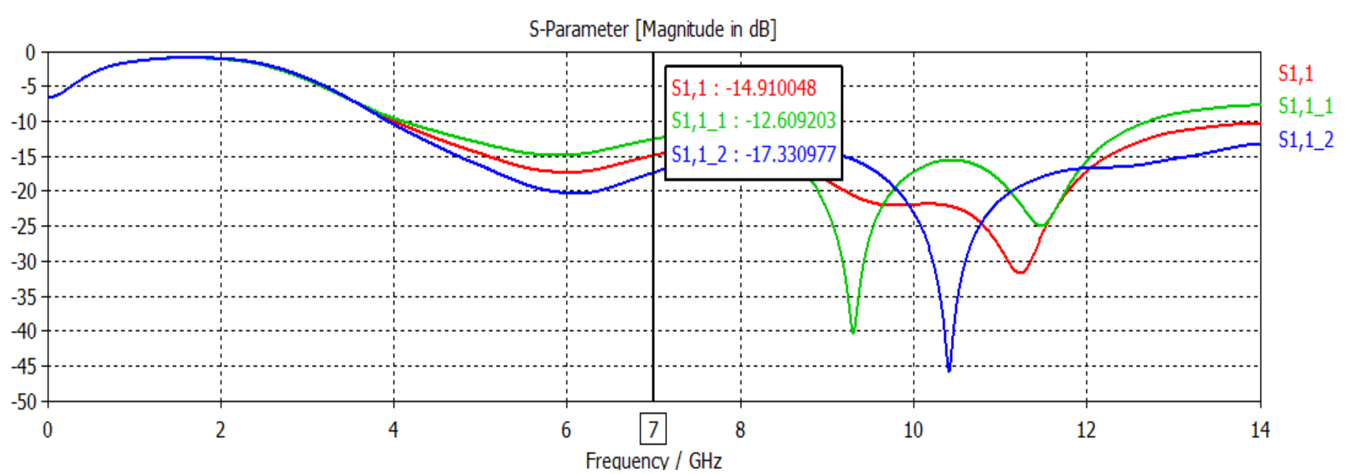


Fig.6.39 Retutn Loss plot wrt W_N

l)Simulated VSWR Plot on Variation of W_N

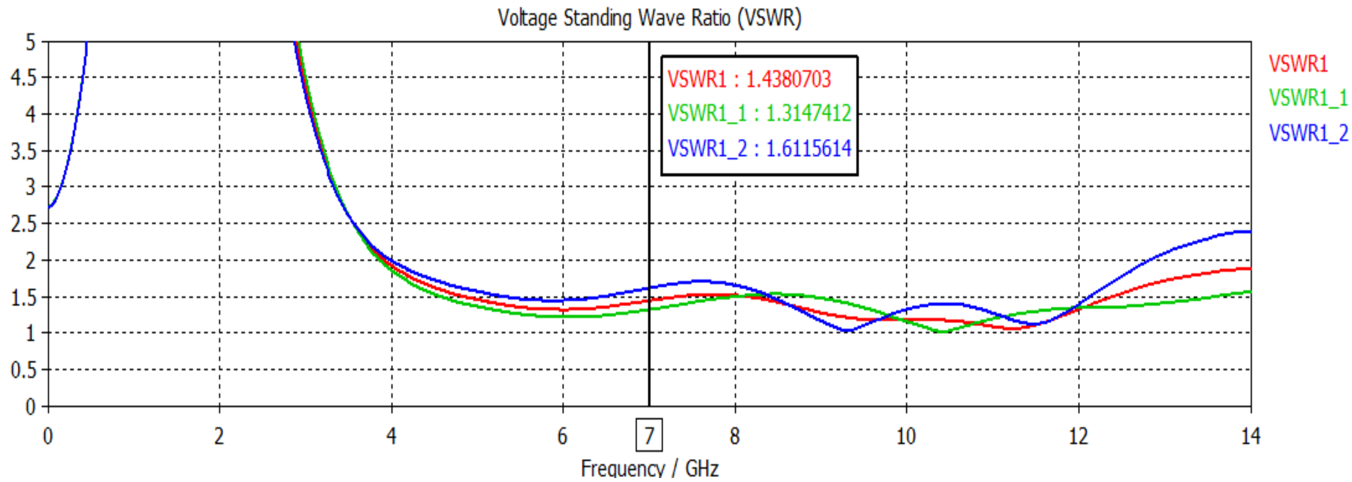


Fig.6.40 VSWR plot wrt W_N

6.5.5 RLC circuit values Extended Circular MPA with Notch and Slit

The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Fig. 6.41

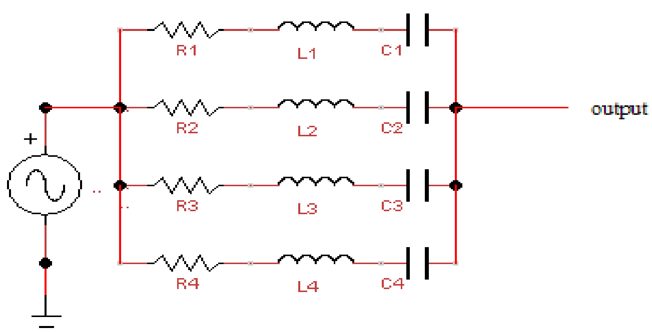


Fig. 6.41 Equivalent RLC Model of Proposed Antenna

The Parameter were calculated with the help of Z_0 =50 ohm= $\sqrt{(L/C)}$, and the parameter were shown in table 6.23

Table 6.23 RLC value for designed antenna

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	4.0	R1= 11.4	L1= 1.9	C1= 0.79
2	6.0	R2= 5.79	L2= 1.32	C2= 0.53
3	9.59	R3= 12.65	L3= 0.84	C3= 0.38
4	11.24	R4= 6.7	L4= 0.71	C4= 0.28
5	14.0	R5= 6.42	L5 = 0.57	C5= 0.23

CHAPTER 7

CONLUSION & FUTURE SCOPE

These above proposed antenna structure's were simulation carried out using the CST Microwave Studio software. The Simulated results are presented, shows the usefulness of the proposed antenna structure for UWB applications. The simulation results of band notch antenna indicate that the designed antenna fulfils UBW band characteristics for various frequency bands and showing the good return loss and radiation patters as well as bandwidth and gain is also enhance which was shown in above results.

From Above Thesis it was concluded that:

1. The first design antenna Operating Frequency Range = 4.53 GHz- 11.026GHz Band width = 7.3 GHz, RL = -10.37dB, VSWR = 1.86 (<2)(acceptable).
2. The second design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range.
3. The third design achieves the return loss of -17.88 dB and the bandwidth of 8.2 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.29 < 2 for entire bandwidth range
4. The fourth design achieves the return loss of -14.05dB and the bandwidth of 10.0 GHz (3.98- 13.98GHz) and corresponding VSWR is 1.48 < 2 for entire bandwidth range
5. The fifth design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range.
6. Also RLC Parameter model os also found out for each antenna
7. For different variation of parameter Rl, VSWR, Gain, and Directivity is also found out.
8. Also the effect of dielectric substrate permittivity is also studied in this thesis. As increment of substrate dielectric constant in antenna design results in the degradation of antenna performance.

Future Scope

New technique is used to reduce the structural dimension of Antenna for different application. In order to reduce the size metamaterial are used. There are neumerous algorithm can be used to optimized the result.

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